CHEMICO-PHYSIOLOGICAL

OBSERVATIONS

ON

PLANTS.

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BY

M. VON USLAR.

TRANSLATED FROM THE GERMAN, WITH ADDITIONS,
BY G. SCHMEISSER, F. R. S. &c.

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TO

THE PATRONS AND PROMOTERS

OF

PHILOSOPHICAL INVESTIGATIONS

IN

GREAT BRITAIN.

PERMIT me, Gentlemen, to lay before you this ſmall Publication, containing ſome ingenious obſervations lately communicated to the public in the German language by Mr V. Uſlar. I embrace this opportunity to make known to you a Gentleman, whoſe laudable endeavours are directed to the improvement of that part of the knowledge of plants and of vegetation, which has hitherto appeared the moſt obſcure, and which has yielded leaſt to the inveſtigations of philoſophy.

I

I have no doubt, but that ſome of you, to whom the various ſciences are already ſo much indebted, will deem it not unworthy of them to examine the contents, and to improve upon what is here delivered. I have purpoſely avoided making any eſſential alteration in Mr V. Uſlar's obſervations, and I have omitted no part which appeared intereſting reſpecting the object of his publication, or which I knew to be not generally known in this country. But I have prefixed a general view of thoſe principles, and of ſuch of their properties, as I thought moſt worthy of attention, in the proper inveſtigation of that intereſting ſubject. As I conſidered part of the obſervations related in the original work, as not yet ſufficiently and accurately aſcertained, and that much muſt ſtill be done towards the complete eſtabliſhment of the theory, I have taken the liberty of inſerting a ſhort ſketch of my ideas reſpecting Light and its properties; in expectation, that this may be honoured with examination, by thoſe who wiſh to contribute towards the improvement or correction of the ſubject of this publication; a ſubject, ſurely well deſerving the attention of experimental philoſophers. Whatever I have to ſay upon, or to add to Mr Uſlar's communications, I have purpoſely poſtponed; as I have many experiments in view, which I ſhall perform with all poſſible accuracy, and of which, I ſhall communicate the reſults at another opportunity.

I hope to give then alſo an account of ſome ſubequent obſervations, which Mr V. Uſlar has promiſed on this ſubject; and to be able to preſent ſome new obſervations, made by the ingenious Mr

Hedwig, whoſe merits are already well known to many in this country; and probably alſo, to make known ſome new diſcoveries, which I anxiouſly expect from Mr V. Humbold, a Gentleman already celebrated among the learned in Germany, by ſome ingenious publications on this ſubject.

I have the honour to be,

Gentlemen,

Your moſt obedient ſervant,

G. SCHMEISSER.

INTRODUCTION.

HAPPILY the time is arrived, when Chemiſts and Phyſiologiſts unite their endeavours to inveſtigate the nature, conſtruction, compoſition, and functions of the vegetable tribe; in order to perfectionate our knowledge of the Economy of Plants, and to diſplay the many intereſting and entertaining particulars, which the ſtudy of this branch of ſcience is calculated to afford.

Many arts and ſciences have already derived great advantages from the aid of chemiſtry, by the many improvements which that important ſtudy has ſuggeſted. But though Botany has met with great admirers, and has been cultivated by many original geniuſes, little has it been advanced in proportion, by chemical and phyſiological inquiries into the nature of vegetables.

Chemiſts by their uſual ardour of inveſtigating every body which preſents itſelf to them, have indeed diſcovered and pointed out, the immediate component parts of vegetables, and their various products or combinations. By aſcertaining many of their chemical properties, they have ſhown how they may be further prepared to ſerve for alimentary, medicinal, and other uſeful purpoſes in the arts and manufactures.

What variety of ſucceſſive phenomena do we perceive in viſiting our gardens, fields, foreſts, and meadows, from early ſpring, till the cloſe of the autumn; when, during this period, plants make firſt their appearance, proceed in their growth, and attain to perfection. But we ſhould not be ſatisfied with admiring their external beauties, with knowing how to diſtinguiſh them by their external characters, and with collecting them or their products whenever they are fit to ſerve for our various purpoſes. Nor are we entitled to enjoy the contemplation of all the phenomena, and receive the manifold donations of thoſe products of nature, nor ſurely to murmur at their accidental failure, or untimely decay, without enquiring more particularly into the cauſes of their diſeaſes, to remove them if poſſible; and endeavouring to inveſtigate the origin and progreſs of all theſe phenomena, and the cauſes whence they reſult: *e. g.* To aſcertain the food of Plants, and the ſituation beſt ſuited to their reſpective conſtitutions, and the means by which they may moſt certainly obtain their proper nouriſhment; to diſcover their natural aſſociates, as well as thoſe which are inimical to them. Laudable, muſt therefore be every attempt or endeavour, which tends towards diſcoveries or improvements on ſo intereſting a ſubject.

It is the expreſs deſign of the preſent treatiſe, to enquire into ſeveral of theſe intereſting particulars. How far the Author has ſucceeded in his endeavours, the candid reader muſt judge.

OBSERVATIONS

ON

VEGETATION.

IN attempting to inveſtigate the economy of vegetables, it is neceſſary to have a general knowledge of thoſe ſubſtances and principles, that are found to furniſh and produce the requiſite ſupplies for the purpoſes of vegetation, as well as of ſuch as may tend to deſtroy theſe ſupplies. Later diſcoveries in chemiſtry have ſhown that theſe principles are chiefly the following:—Matter of HEAT:—Matter of LIGHT:—OXYGEN:—HYDROGEN:—AZOTE or NITROGEN:—CARBO:—and their combinations.

HEAT.

THIS elementary principle, exiſting in all bodies, manifeſts itſelf by numerous phenomena reſulting from its effects. It exiſts in different ſtates according to circumſtances afterwards to be mentioned.

In one, (probably its original ſtate,) it is not perceptible by our organs of ſenſation, and is apparently inactive upon other bodies exiſting within its atmoſphere. This ſtate of heat, properly defined Latent Heat, is the ſource of all its other ſtates, in which it becomes ſo powerful an agent for innumerable purpoſes neceſſary for organized bodies. Immortal, therefore, be the name of that great philoſopher, DR. BLACK, to whom we are indebted for its complete diſcovery, which has led to ſo many ſubſequent uſeful diſcoveries in chemiſtry.

Latent heat, we find, exiſts in different proportions in different bodies; and bodies have a different capacity of imbibing, accumulating, and combining with it.

The other ſtate of heat, is that in which it manifeſts itſelf to our organs of ſenſation; and in which it becomes active upon bodies preſented to it. This ſtate is occaſioned by different cauſes. For inſtance, latent heat is ſet at liberty, ſo as to become active, by certain exchanges of the condition, or component parts of bodies, reſulting from ſuperior elective attraction among heterogeneous bodies, when brought into near contact; as we obſerve, by the ſeparation and exchange of the baſis of oxygen gas, in the proceſs of combuſtion and reſpiration;--by the converſion of vapours into liquids, and of liquids into ſolids;--by the cryſtalliſation and ſudden concretion of ſaline, vegetable, and animal fluids;--by the ſudden abſorption and condenſation of fixed air and water by earths, &c.

Whenever heat, in any of the above-mentioned caſes, is ſet at liberty from a body, it always diſcovers a tendency to enter and pervade another preſented to it, owing to its general attraction for all bodies; on which account it cannot be confined, nor exiſt, in a perfectly free, or uncombined ſtate.

The different degrees in which heat becomes more or leſs perceptible and active when ſet at liberty, will be in proportion; firſt, to the quantity of latent heat in bodies; ſecondly, to the quantity which is ſeparated in a given time from bodies acting upon one another. Its effect on the ſubſtances to which it is applied, will be according to the velocity with which it can enter that body, and alſo in proportion to the capacity of the ambient, or intervening medium, for accumulating or retaining it. If, for inſtance, a homogeneous body, or alſo a chemical compound, be expoſed to ſuch a degree of heat as is incapable to deſtroy the chemical attraction of the parts of the compound, it then will gradually produce an equal effect upon ſuch aggregate; namely, it will merely enter, occupy, and be accumulated in the moſt minute interſtices of that body, and thus exert its expanſive force, or ſelf-repelling power, and thereby increaſe the bulk of the body, diminiſh its ſpecific gravity, and occaſion an alteration in it, which will continue only as long as heat is ſupplied; and the expanſion will be in proportion as the quantity of heat ſupplied can overcome more or leſs the power of attraction of coheſion of particles, under the preſſure of the atmoſphere. In this caſe, on removing the body from the ſupply of ſenſible heat, its parts will reſume their former ſtate without having undergone an alteration in their nature; conſequently, the heat applied to ſuch had only produced a temporary effect. Examples of this we obſerve in the converſion of ice into water,—of water or ſpirits of wine, or eſſential oils, into vapour,—in the melting of wax, fat, gelatinous matter, metals, &c.

There are other caſes, in which ſenſible heat when induced in a moderate degree, upon bodies of a heterogeneous mixture, will firſt occaſion a ſimilar effect; yet ſuch bodies will be more or leſs decompoſed or deſtroyed by an intenſe heat.

Inſtances of the effect of a moderate degree of heat occaſioning a mere ſeparation of the conſtituent parts of a mixture, without the production of a new compound, we can obſerve, on applying a moderate heat to a mixture, of fixed ſalt and water, of ſpirits of wine and water, of water and earthy matter,—to animal and vegetable fluids,--oils, and other vegetable matter, &c. In this caſe, the applied heat firſt pervades and expands the mixture, and then accumulating, gradually exerts a different effect upon each of the bodies, which effect will be in proportion as their capacity of retaining heat is to the power of attraction and coheſion between the particles of each of the bodies in the mixture. If, therefore, the capacity of one of the bodies (as water), for accumulating heat, exceeds the power of attraction of coheſion among its particles, and if the power of attraction of coheſion among the particles in the other body (as ſalt), exceeds its own power of accumulating heat, then the expanſive force of heat upon the particles of water, will be greater than that upon the particles of the ſalt, and as thus the ſpecific gravity of water is diminiſhed, the latter will conſequently ſeparate firſt, and will remain ſuſpended in the atmoſphere until it part again with that heat. When this happens, the water recovers its former ſtate, and the ſalt remains undecompoſed, parting likewiſe gradually with its ſhare of accumulated heat and then the applied heat will be ſet at liberty again.

Another effect of ſenſible heat applied in a great degree to bodies of a heterogeneous nature, is a more permanent alteration or a total exchange of the component parts. Here a certain portion of ſenſible heat combines chemically or more intimately with ſome of theſe parts, and becomes thus latent, producing a new permanent and elaſtic compound (or gas), in which the heat remains in combination in the temperature of the atmoſphere in which it then exiſts, and can from that ſtate be ſeparated only by expoſing it to ſuch a body, as has a ſuperior elective attraction for the ſubſtance to which it is combined. For inſtance, if we expoſe animal or vegetable juices, incloſed in a veſſel, to a moderate heat, we obſerve, that the aqueous or more volatile parts firſt ſeparate, and the leſs volatile remain; but when more heat is applied, then an exchange, or new combination of the component parts of the reſiduum will take place, and part of the applied heat will enter into a chemical or more permanent union with ſome of the principles of the compound, and produce thereby hydrogen gas; or it will combine with a new compound, as carbonic acid, and form the fixed air. Thus we perceive, that no ſpecific effect can be appropriated to ſenſible heat, ſince much depends on its quantity and on the diſpoſition of bodies, either to accumulate merely or to combine it.

Senſible heat in a moderate degree applied, promotes vegetation in a variety of ways; it excites the activity of plants; it promotes the diſpoſition

poſition of ſome of their conſtituent parts for new attraction and combination, to obtain ſuch ſubſtances as may be requiſite for their growth; it likewiſe cauſes them to reject ſuch matters as would be hurtful to them in retarding their growth, &c.; it promotes the diſſolution or digeſtion, the formation, and ſecretion of their different products.

It ſupports the irritability of ſome of their parts, in diſpoſing them to acquire and to retain a due proportion of the principle (the oxygen hereafter to be explained) which cauſes their irritability; and in preventing alſo the accumulation of this principle in plants, which may become hurtful to them.

It renders their food and juices, &c. more fit for penetrating and paſſing their different conducting canals; and enables them to diſpoſe of their ſuperabundant portion of fluids, by promoting perſpiration and evaporation.

It is alſo active in the production of electricity, which likewiſe aſſiſts vegetation.

Senſible heat becomes alſo uſeful to vegetation in another way: after plants or animals have finiſhed their period of life, or when purpoſely deprived of it, heat then occaſions a diſſolution, and new combination of their component parts, by fermentation, &c. according to the nature of the vegetable or animal matter; and thereby promotes the preparation of new food for living plants.

Thus we obſerve the numerous beneficial effects which heat has upon the proceſs of vegetation.

But heat may prove fatal to the conſtitution of plants when applied in too great a degree, and for too long a time; as this may occaſion a too rapid digeſtion and perſpiration of their nouriſhment, and conſequently an exhauſtion. In ſuch caſes, plants will only recover by diminiſhing gradually the application of ſenſible heat, either by occaſioning a ſlow evaporation of water upon their parts, or by other means.

LIGHT.

LIGHT I conſider as a matter exiſting in bodies, and which, like matter of heat, may exiſt in different proportions in different bodies. It can manifeſt itſelf in various ſtates, according to the capacity of bodies, for attracting, detaining, or combining with it, whenever it is ſet at liberty from one body, and induced upon another.

Light, in many of its properties, appears to differ from matter of heat; but heat ſeems to be a neceſſary agent for its perceptible and active ſtate. I am alſo of opinion, that the production of the ſenſible ſtates of both light and heat, reſults from their mutual action upon each other when excited.

Light does not enter into the compoſition of all bodies. Such as do not contain it, are not fit for inflammation, as earths, &c. but ſuch bodies may imbibe a ſmall portion of light; but they can retain it only under certain circumſtances connected with the nature of their compoſition and ſtructure, and according to the degree of external preſſure acting upon them.

Bodies which contain light in their compoſition, and which are neceſſary for inflammation, or for the production of perceptible and active light and heat, and which in the combination with oxygen produce no permanent gas, I ſhall call *perfect inflammable* bodies, ſuch as ſulphur, phoſphorus, hydrogen. And ſuch bodies as contain it only in ſome of their component parts, and which produce gas during their inflammation, I ſhall call *ſemi-inflammable* bodies; as oils, camphor, ſpirit of wine, wood, &c. And we may thence ſuppoſe, that bodies contain more or leſs light in their compoſition, in proportion as they exhibit the phenomena of inflammation, when properly diſpoſed for it.

Light and heat may, at the ſame inſtant, be ſeparated from certain bodies (though not ſtrictly inflammable).

1ſt, By external cauſes, as by colliſion, friction, or condenſation. The production of ſparks, when two bodies, as flint and ſteel, &c. are ſuddenly and violently ſtruck together, affords a familiar example of this ſeparation.

2dly, Light may be diſengaged from its combined ſtate, by the mutual action and new combination of certain heterogeneous bodies. To occaſion this, it is not only neceſſary that at leaſt one of the bodies be an inflammable one, and that thoſe bodies which are to act upon one another have a chemical attraction for combination, and be aſſiſted by ſenſible heat neceſſary to promote their attraction; but alſo, that the one body have an attraction for the baſis of the inflammable body, ſuperior to that which the baſis has for light.——Farther, two heterogeneous bodies, whatever they may be, which have no chemical attraction for one another, cannot combine, and conſequently cannot

not emit ſenſible light and heat. Hence we obſerve no ſuch interchange takes place on mixing ſulphur or phoſphorus, with gold, platina, &c.; or hydrogen with ſulphur, or phoſphorus, expoſed to ſenſible heat. An intimate combination of ſuch a nature, therefore, of two bodies, as mentioned before, is neceſſary for the production of inflammation.

Senſible light thrown upon bodies which do not tranſmit nor reflect it, but which imbibe it, but do not retain it, ſeems to diſengage their latent heat; and combining with the latter, gives to it elaſticity, and thus produces by ſuch combination ſenſible heat.

We likewiſe obſerve, that inflammable bodies cannot produce the phenomena of inflammation, or emit ſenſible light without the aſſiſtance of ſenſible heat; and many inflammable bodies will not part with their latent heat, unleſs their latent heat is excited by ſenſible light. In the inflammation of an inflamed body, a mutual action and re-action of both principles appears to take place: and accordingly it ſeems that camphor, reſin, ſpirit of wine, oils, &c. will not inflame by the mere application of heat: but they will do ſo if ſenſible light, accompanied at the ſame time with ſenſible heat, is applied; as, for inſtance, in the caſe when the inflammable body is excited by flame.

It likewiſe appears, that heat alone cannot diſpoſe all inflammable bodies to combine with the oxygen from the atmoſphere; the matter of light latent in theſe bodies having perhaps a greater attraction for either of their combined parts; and that they will therefore not give out their light until their latent heat be at the ſame time excited by the action of ſenſible light applied.

When light is ſet at liberty during this combination, it will then be viſible or not, according as it is, or is not, diſpoſed to combine with another matter, in the moment of its being ſet at liberty. For inſtance, when light ſet at liberty, is immediately, either partly or wholly, diſpoſed to unite with another matter, as that of heat, to produce elaſtic ſenſible heat; or when that again is employed for the production of gaſſes or vapours, then little or no light will become perceptible, and more ſenſible heat will reſult accordingly from it. But when light is ſet at liberty in a greater proportion from the inflammable body, than what the matter of heat in thoſe excited bodies can conſume, or combine with, for the production of ſenſible heat, and where no elaſtic fluids are produced which can take it into their compoſition; then more light will become perceptible, and in proportion active.

The perceptibility, or active power of the light extricated, will be greater in proportion as the excited bodies yield that principle in a greater quantity, and as the velocity with which it can enter the bodies is greater, and as bodies can combine more readily with it. The more ſlowly the combination of ſuch bodies takes place, the leſs will be the quantity of light ſeparated at the time, and conſequently, the leſs its effects.

As the diſpoſition of bodies for chemical combination is promoted by heat, it therefore ſeems that heat is a neceſſary medium for inflammation; and that, therefore, much depends upon the degree in which that agent is applied to bodies diſpoſed for combination. We obſerve but a ſmall quantity of viſible light by expoſing phoſphorus or ſulphur in the atmoſphere of a low temperature, and a great portion, when more heat is applied.

We ſhall now endeavour to explain, how oxygen gas is not always neceſſary for the production of light and heat. The combination of other bodies may occaſion the ſame phenomena, provided that one of the bodies be an inflammable one, and conſequently containing light, and that all the other circumſtances formerly deſcribed be preſent. For inſtance, if we diſpoſe ſulphur and certain metals, as iron or copper, for combination effected by heat, we perceive the ſame phenomena, namely, the production of light and heat, without their being expoſed in oxygen gas, or any other gas containing that principle; which experiment was lately performed by ſome well known Dutch chemiſts, and which any one may eaſily repeat: indeed the above-mentioned ſubſtances will exhibit the phenomena in azotic or hydrogen gas, or in a vacuum; but inflammable bodies, expoſed in either of thoſe gaſſes *per ſe*, cannot do this, becauſe they do not under theſe circumſtances enter into combination with the baſis of either of the gaſſes, which would be neceſſary, as obſerved before.

Oxygen can only produce theſe phenomena, when it is expoſed to inflammable bodies for which it has an attraction of combination, ſuch as ſulphur, phoſporus. And it produces the phenomena in a greater degree than other ſubſtances, from its ſuperior and more rapid attraction for, and combination with thoſe bodies; and likewiſe, from the circumſtance, that the combinations of theſe bodies are not attended with the production of gaſſes and vapours. It may now be perceived, how oxygen is a neceſſary medium for the production of light from ſuch inflammable bodies as are chiefly compoſed of hydrogen, as ſpirits of wine and oils.

Oxygen is likewiſe requiſite for the production of ſenſible heat in the combuſtion of charcoal, as it has a ſtrong attraction for that ſubſtance. From theſe and other obſervations we conclude, that more ſenſible light and heat are produced by inflammation, in proportion as that proceſs is leſs attended with the production of elaſtic fluids.

If, therefore, the proportion of hydrogen exceeds that of carbo in ſemi-inflammable bodies, then there will be more light ſet at liberty; and on the other hand, if the carbo predominates, there will be leſs light and more heat.

Now, in the inflammation of ſpirits of wine, oils, &c. in oxygen gas, there are both light and ſenſible heat ſet at liberty, which continue perceptible, as long as the ſupply of both continues. But, we perceive, that this proceſs is attended with a continual loſs of light and heat; which is to be accounted for, as a certain quantity of light is immediately employed in the production of ſenſible heat, from the inflaming body; that a great quantity of heat is likewiſe employed in the production of fixable air, ariſing from the combination of carbo in the ſemi-inflammable body, and the oxygen from the atmoſphere; and alſo, that another portion of ſenſible heat is employed for the formation of vapours from the water which is formed by the combination of oxygen from the atmoſphere, and the hydrogen in the ſpirit of wine: Whereas, by the combination of phoſphorus or ſulphur, there is no heat combined, and there is no gas and no vapour produced, as explained before; and that portion only of light diſappears,

pears, which was neceſſary to excite the latent heat in thoſe bodies.

Light, when thrown upon bodies, which do not tranſmit nor reflect it, but which have a capacity of imbibing it, may become active upon ſuch bodies, as is the caſe in plants, either by combining ſtrongly with their latent heat, and converting that into ſenſible heat; or by occaſioning, at the ſame time, a ſeparation of the oxygen or other matter of ſuch bodies, with which it can combine; and thus, in conjunction with matter of heat, produce elaſtic fluids: or it may partly be detained in bodies; and ſuch bodies will emit it gradually again in the ſtate of viſible light; as we obſerve of certain ſubſtances. This property of accumulation and emiſſion of light by certain bodies, is more perceptibly occaſioned in them, when previouſly prepared for it by the effect of heat; firſt in producing by heat an expanſion of ſuch bodies; then expoſing them to a ſtrong light, as that of the ſun; ſuch bodies will, in proportion as they poſſeſs thoſe mentioned qualities, imbibe more or leſs of that light, and will give it out again in a viſible ſtate, in proportion as they contract, and when placed in a dark room. This we obſerve in a certain ſpecies of heavy ſpar, called Bononian ſtone, and other ſubſtances. There are ſalts which, when expoſed to much light during their cryſtalliſation, will afterwards emit light; other ſalts will emit light when rubbed in a mortar in a dark place; as, for inſtance, the corroſive ſublimate, &c.

Light thrown upon bodies, which do not tranſmit nor combine, but which reflect it, produces no ſenſible heat upon them, and it ſuffers no change. This we obſerve when ſenſible light is thrown upon certain metals with a poliſhed ſurface.

Senſible light, falling upon bodies which are tranſparent, as glaſs, gaſſes, &c. when perfectly homogeneous, is tranſmitted, and has no apparent effect upon them. Thus the more homogeneous that ſuch bodies are, the leſs is the diminution of the intenſity of the light which pervades them, and the leſs is the ſenſible heat which is produced in them. This coincides with M. De Luc's opinion, that there is in proportion more light induced upon bodies, exiſting on or near the ſummits of high mountains, and conſequently leſs heat produced in that atmoſphere; and that there is leſs light reaching the ſurface of lower ground, as the light deſcending through the lower region of the atmoſphere to the earth, is partly abſorbed, and variouſly interrupted by the heterogeneous bodies in the lower atmoſphere, by which the intenſity is greatly diminiſhed.

From what has been obſerved reſpecting the properties of light, we may perceive in what reſpect light may be beneficial to plants in general.——Light induced upon plants, may excite heat, occaſion the ſeparation of oxygen, and convert other matters into elaſtic fluids. It may greatly contribute to the formation of the inflammable matter produced in plants, ſuch as oils and reſinous matters. The formation of ſuch ſubſtances is very remarkable in hot climates, and perhaps chiefly depends on the faculty poſſeſſed by light of ſeparating the accumulating oxygen, as oxygen deſtroys the inflammability of bodies.

Light, therefore, ſeems thus to promote the increaſe of inflammable matter, only in thoſe plants whoſe component parts have not a greater attraction for oxygen, than the oxygen has for light and heat, as we may expect in plants which aſſume an acid nature.

Light induced upon plants occaſions a change in their colour, either by entering into their conſtitution, or by ſeparating the oxygen which cauſes, in proportion to its quantity, a modification of their natural colours; and by which ſeparation of oxygen, it ſupports the irritability of plants, as that appears to depend upon this principle, as has been before obſerved.

Living plants diſcover a diſpoſition to attract light, and when in want of it, ſearch for it, and direct the extenſion of their tender or flexible parts towards a place where they can reach it. Certain parts of plants, as flowers, manifeſt a diſpoſition to preſent themſelves, ſo as to receive fully the rays of the ſun, or they direct their faces towards the ſun: This diſpoſition, Mr Girtanner aſcribes to the effect of light upon certain fibres peculiarly conſtructed, as will be ſeen in the ſequel of this book.

I ſhall finiſh the ſubject of light with the obſervations, that plants may receive light from gaſſes which contain it, as before mentioned, by imbibing and decompoſing them; and that plants may thus receive light, when growing in a ſituation excluded from the ſun, as in thick foreſts.

OXYGEN.

OF all the principles neceſſary for the ſupport of organized bodies, oxygen may be conſidered as one of the moſt active. It received that name, which ſignifies the *generator of acids*, from its inveſtigator MR. LAVOISIER; who found it to be a neceſſary principle in the formation of acids. The exiſtence, and ſome of the properties of this principle, were already known to, and related by, Dr. John Mayow*; and alſo by Dr. Rutherford, the diſcoverer of phlogiſticated air. But Lavoiſier has certainly inveſtigated its properties, and active powers, more than any other chemiſt; and has conſequently the greateſt merit. It exiſts in different bodies, variouſly combined, and manifeſts itſelf, by the various effects which it produces when ſeparated from any of its combinations, and when acting upon other bodies, and entering into a new combination with them.

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* In a Treatiſe publiſhed in 1674.——Oxford.

It is ſet at liberty from its combined ſtate in conſequence of other bodies acting upon it, or upon the ſubſtances with which it was combined, by a ſuperior power of chemical elective attraction. *1ſt*, It exiſts in water, combined with hydrogen. *2dly*, In the atmoſphere, combined with matter of heat, (and as I believe, likewiſe with light) and conſtitutes, in that ſtate a part of the atmoſphere, to which it gives the quality of ſupporting life, combuſtion, and inflammation. *3dly*, It exiſts in fixed air, combined with carbonaceous matter, to which it has a ſtrong attraction. *4thly*, It is the principal component part of acids, combined with the acidifiable ſubſtance of animal or vegetable matter. *5thly*, It exiſts combined with metals, which it deprives of their luſtre, inflammability, coheſion, &c; and, which are thereby rendered capable of entering into different combinations with other bodies. It has, when applied to vegetables, a great effect upon their growth; and, when plants are too much deprived of it, or when they are overloaded with it, it then proves hurtful to their conſtitution. It contributes to the motion of plants, as it cauſes the irritability of ſome of their parts; and the various degrees of this irritability depend on the different proportions in which it enters, or is accumulated in them. The due proportion, which plants thus require for their irritability, &c. depends, likewiſe, upon the ſubſtances which ſurround and act upon them. The ſupply of this principle is produced by ſuch ſubſtances as contain oxygen; and this, the more readily, according to the weaker combination of the oxygen with the other ſubſtances with which it is united: Hence, combinations in which the oxygen is retained with very little force, as for inſtance, ſuper-oxygenated muriatic acid, are moſt fit for that purpoſe; for plants can only obtain the oxygen from its other combinations, in ſo far as they have a power of occaſioning a decompoſition of theſe combinations. But this power depends much on the temperature in which the plants grow.

Whenever plants imbibe oxygen, in a greater proportion than what they naturally require; (which may be occaſioned by the abſence or diminution of the principle which cauſes the ſeparation of oxygen), then an accumulation of oxygen takes place, which occaſions a proportionally greater degree of irritability; and which, conſequently, may become hurtful to the conſtitution of plants.

The principles which cauſe the ſeparation of the oxygen, are light,--hydrogen, aſſiſted by heat. Hence, the due proportion of oxygen in plants, depends on the different degrees in which any of theſe principles are applied, or can act upon them. Thus, a moderate portion of theſe exciting principles will occaſion a preſervation of the due quantity; a leſs degree, an accumulation; and a greater degree, a diminution: The two laſt will occaſion a gradual exhauſtion of ſuch plants.

Oxygen has alſo a great effect upon the colours, and upon various parts of plants; and greatly contributes to the formation of their products. It is an aſcertained fact, that the ſuper-oxygenated muriatic acid, which has been found to conſiſt of 1,856 parts of muriatic acid; 98,105 of water; and 0,093 of oxygen, deprives green plants of their colour; or changes them into white, yellow or reddiſh. What takes place by that acid immediately, can but ſlowly proceed by the oxygen in the atmoſphere, owing to the almoſt equal attraction which oxygen has for the colouring matter of the plants, and for the matter of heat and light.

It appears, that the colours of plants become paler the more oxygen they imbibe, and that the modifications of the green colour depend on the different proportions of oxygen. Thus, we may explain many phenomena that occur during the vegetation of plants. The *bilum* of young ſeeds is generally colourleſs, ſo are the *petals* of the flowers, when perfectly included in the *calyx*.——Leaves, when they firſt appear, are of a pale colour; owing probably to the oxygen, which, at that period only, begins to be extricated by the effect of light and ſenſible heat; and thus permits the colouring matter to make its appearance. In the ſame manner, may the change of the green colour of leaves into yellow, which we obſerve in the autumn, be explained. Vegetation generally ſtops in that ſeaſon, and plants then approach to their winter's reſt; the ſecretion of oxygen diminiſhes, and the quantity gradually accumulates during that time, and conſequently deprives them of the green colour.

The extraction of oxygen from plants by the effect of radiant light, ariſes perhaps, from the ſuperior attraction of oxygen for light. Some plants, as tremella,—noſtoc,—filices,—muſci,—and algæ, retain the oxygen weakly, and part with it eaſily.

This explains how plants change their colours, by the free acceſs of air; why plants growing in the ſhade have generally a pale colour; and why plants, entirely excluded from light, loſe their colour; as in that caſe they are deprived of, or excluded from, thoſe agents which occaſion a ſecretion of the accumulating oxygen, on which the change of colours chiefly depends *.

The ſeparation of oxygen from plants, may be aſcertained, by applying a little diluted acid, ſuch as oxalic, nitric, &c. Plants, or their parts, which contain much oxygen, and part

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* That hydrogen gas, applied to plants excluded from light, occaſions a ſeparation of their accumulating oxygen; was firſt aſcertained by Mr. Humbold.

part eaſily with it, are generally green; and thoſe which contain a great portion, but loſe it with more difficulty, are, in proportion, either white, or ſpotted: As for example, Lichen *miniatus*,—L. *parietinus*,—L. *verrucoſus*,——different petals,—ripe apples,—barks,—and bracteæ, when growing in the ſhade.

The different effects which oxygen produces upon plants, when growing in different places, and expoſed to a different atmoſphere, have led ſeveral botaniſts to miſtake trees of the ſame ſpecies: For example, the betula and tinus, growing upon the *Brokken*, (a high mountain in Germany on the Harz) on account of their ſmaller ſize, and deeper colour of the leaves than uſual, when growing in a different atmoſphere, have been miſtaken for new ſpecies. Such variations had been aſcribed to the effect of different climates and ſoils; but botaniſts did not ſuſpect, that any ſuch effect aroſe from that great agent oxygen.

The cauſe of the deeper colour of thoſe plants, or of their leaves, is probably,

a. The more intenſe light, tranſmitted through the atmoſphere ſurrounding the ſummit of ſuch a mountain, and acting freely, on all ſides, upon thoſe ſolitary trees.

b. The different ſtate of the purity of that atmoſphere, and the ſuperior capacity of that fluid for receiving oxygen.

c. The ſtronger, and more laſting cold, which cauſes a great alteration in the irritability of plants by the increaſe of oxygen; which is, in proportion, ſeparated again by each increaſing degree of light.

The effect of light, oxygen, and carbo, upon colour, is equally obſervable in animals and plants. Beſides the well known obſervations, that the products of hot climates are of a deeper colour than thoſe of the northern; Mr. Uſlar obſerved, that he found repeatedly, the rana *arborea* change its colour, by living in different ſituations; the more it was expoſed to the ſun, the deeper its green colour became; and the green colour changed into a whitiſh grey, as he obſerved alſo of ſome plants, when it had lived a conſiderable time moſtly excluded from light, or when confined within walls. Perhaps, aliment, climate, and confinement, contribute to the change of colours in organized bodies.

The exiſtence of oxygen in plants, is ſhown by their becoming acidified, or oxydated; and by their undergoing an acid fermentation. Beſides, it is found, that certain plants contain perfect acid in their compoſition. Such are generally of a pale green colour, as the oxalis *acetoſella.* The boletus *ſuberoſus* yields ſaccharine acid during its growth. The oxygen gas which, we obſerve, is extricated from plants when expoſed to the effect of light, &c. affords another proof that they contain oxygen, or take it into their conſtitution.

The colouring matter of plants appears to reſide in, or to be produced in, the reſinous parts, in combination with oxygen: For inſtance, if we extract the green parts of plants by ſpirits of wine in a veſſel excluded from light, filter the infuſion, and fill with it a phial half full, and expoſe it ſlightly corked to the rays of the ſun, or to the light of a large burning lamp; we then obſerve, that the green colour ſoon inclines to yellowiſh. This change, however, does not take place if the bottle is totally filled, or excluded from the acceſs of pure air; nor when the infuſion is kept in a phial, in contact with nitrogen or hydrogen gas. So we find, that the tincture of turnſol, when excluded from light, retains its colour, but loſes it on expoſure to much light.

Oxygen renders many volatile ſubſtances more fixed in the fire; as we obſerve of ſulphur, phoſphorus, and vegetable ſubſtances, when combined with it. It alſo deſtroys the inflammability of bodies by its combination. Though it appears, that oxygen, when in great proportion, covers the colours of plants; yet it likewiſe ſeems, that in a ſmall proportion, it contributes to the formation of certain colours. Thus, Dr. Bancroft, in his learned treatiſe on permanent colours, attributes the black colour of charcoal to the combination of oxygen with the carbonaceous matter; and he conſiders the charcoal as an oxyd of carbon. He obſerves, that the tincture of violets, when it has loſt its colour in cloſe veſſels, recovers it by oxygen gas.

Oxygen ſeems alſo to be the principal cauſe of the different colours of the oxyds of metals.

We ſhall conclude this article, with an extract, containing the reſult of the ingenious obſervations made by Fourcroy; who proved the exiſtence of oxygen in plants, by analytical and ſynthetical experiments. He obſerves,

1. That oxygen combined with vegetables alters their colour:

   a. Their colour becomes paler by an increaſe of oxygen,

   b. Deeper by a diminution of it.

2. The various modification of colours, exhibited by plants, depends on the different proportion of oxygen, which they take into their conſtitution.

3. Plants ſaturated with oxygen loſe their green colour entirely; and a yellow colour is the reſult of the change.

4. Plants not ſaturated with oxygen, may appear violet, blue, brown, or purple.

5. Oxygen entering into the conſtitution of plants, occaſions a change in their nature, in proportion as they imbibe it. Oxygen likewiſe appears to be favourable to the formation of reſinous matter.

HYDROGEN.

HYDROGEN.

THIS principle we cannot, as yet, exhibit in a ſeparate ſtate, its properties are only diſcoverable by its combinations. In its combined ſtate it manifeſts remarkable phenomena, which differ according to the nature of the ſubſtance with which it is combined.

It exiſts principally in the compoſition of water, which has been verified by ſynthetical experiments, made by the ingenious philoſopher MR. CAVENDISH, and Lavoiſier; and it thence received its name, which ſignifies the *generator of water*.

In the compoſition of water, it is combined with oxygen, and in this ſtate it is not immediately inflammable; but, when that combination is deſtroyed, by the effect of a ſuperior elective attraction, of certain bodies, for the oxygen with which it has united; as for inſtance, by metallic ſubſtances or charcoal; it then is ſet at liberty, ſo as to enter into another combination; in which caſe it aſſumes a different ſtate, and exhibits different phenomena, according to the nature of the matter with which it combines.

If it unites merely with ſenſible heat, it then produces a compound which is inflammable, or which, when light and heat is applied to it in contact with atmoſpheric air, is capable of exhibiting the phenomenon of inflammation; in that ſtate it is called hydrogen gas or inflammable air.

This compound elaſtic fluid is lighter than atmoſpheric air, or any other gas; it does not ſupport life nor combuſtion like oxygen gas; but it is in that ſtate, capable of diſengaging the accumulated oxygen from plants as obſerved before. When it is ſet at liberty from the compoſition of water, without the preſence of a ſufficient quantity of ſenſible heat, it then has a diſpoſition to unite with other matters; as, for inſtance, with carbonaceous matter, and may thus produce an oily compound, or enter into other compoſitions, and thus become an aliment to plants.

Sometimes we obſerve, that plants emit hydrogen in the ſtate of inflammable air; ſuch as, Dictamnus *albus*, or Fraxinella, when it is in flower; and likewiſe moſt of the fungi and byſſi, by reaſon of the greater attraction of their component parts for oxygen.

Sometimes the hydrogen gas thus emitted by plants is obſerved to have united with a little of carbonaceous matter; and in that caſe, the heavy inflammable air is produced; ſuch is the air emitted by agaricus *campeſtris*.

Occaſionally we find plants containing ſulphureous or phoſphoric matter; and ſuch plants may emit the hydrogen in the ſtate combined with either of theſe, and it will therefore appear in the ſtate of either hepatic air or phoſphoric gas.

AZOTIC PRINCIPLE.

THIS matter we cannot exhibit in a ſeparate ſtate, its properties are only diſtinguiſhable in its various ſtates of combination.

In the ſtate combined with heat, it was firſt diſcovered by the eminent Chemiſt, DR. RUTHERFORD, Profeſſor of Botany at Edinburgh; it was then called Phlogiſticated Air, but now Azotic Gas, on account of its having the oppoſite quality to that principle which ſupports life. It exiſts in the ſtate combined with heat in the atmoſphere; and mixed with a certain portion of oxygen gas, it forms the eſſential compoſition of atmoſpheric air.

It exiſts in the atmoſphere, apparently for the purpoſe of modifying the effect of that powerful agent, the oxygen, in the proceſs of reſpiration

tion of animals and plants; as oxygen gas alone may become hurtful in many reſpects. It ſerves alſo for modifying the rapid effect of oxygen during combuſtion and other operations, and thus alſo enables us to modify the heat extricated from bodies during their decompoſition and combination.

It is moſt likely, that in that ſtate in which it exiſts in the atmoſphere, it enters into combination with another body, and produces new compounds.

It conſtitutes, according to the diſcovery of Cavendiſh, Lavoiſier, and Prieſtly, the baſis of nitre and nitrous acid, and alſo of nitrous air; theſe three ſubſtances differ from one another, only in the proportion of the oxygen to the azotic principle, of which the latter, the nitrous air, contains the ſmalleſt; but this has a ſtrong tendency for ſaturating itſelf with oxygen whenever it can receive it from a ſurrounding body, as, *e.g.* the atmoſphere; and hence it has been found uſeful for aſcertaining the quantity of oxygen gas contained in certain mixtures of gaſſes, as in the atmoſpheric air, &c.; as may be ſeen from the publications of different authors, as Dr. Prieſtly, Ingenhouz, &c.

The azotic principle combined with a due portion of oxygen, forms nitric acid; this has a ſtrong diſpoſition to combine with many other bodies, as *e. g.* with alkaline ſalts, in combination with which it is found in certain plants and earths.

The azotic principle has alſo, when ſet at liberty, an attraction for hydrogen; with which, when combined in a due proportion, it forms ammonia or the volatile alkali, a ſubſtance likewiſe found in ſome plants, united with acids.

Azotic gas, or azote combined with heat, may be obtained free from oxygen, with which it is mixed in the atmoſphere, by expoſing to atmoſpheric air a body which has a ſuperior elective attraction for the oxygen, and which will therefore abſorb the oxygen; as for inſtance, phoſporus or heated ſulphur. It is ſet at liberty when mixed with fixable air, by the proceſs of combuſtion of charcoal, or more difficultly by reſpiration.

When combined with heat, it cannot ſupport life nor combuſtion; and therefore, its preſence, when not accompanied by oxygen, muſt be more or leſs hurtful to animals and vegetables in the proceſs of reſpiration, &c; yet its other qualities ſoon prevent the bad effect which might ariſe from its preſence: As for example, its being lighter than atmoſpheric air, cauſes it to riſe in it, or to leave that part of the atmoſphere where it has been deprived of the oxygen either by the proceſs of reſpiration or combuſtion, and conſequently, it is carried off from the place where it might have been hurtful to organized bodies, and have interrupted the proceſs of combuſtion.

Moſt plants ſoon die when expoſed in it, but there are ſome which continue to grow in it, ſuch as Lichen *verticillatus*,—L. *aidelus*,—L. *radiciformis*—L. *pinnatus*, and moſt of the byſſi;—Agaricus *acephalus*,—A. *aberuntius*,—Boletus *botryoides*, &c; according to the obſervations of Mr. Humbold, and Scopoli.

CARBON.

CARBON.

THIS matter we conſider as one of the principal conſtituent parts of vegetables. And it appears, that it enters and accumulates in the conſtitution of plants in proportion to their ſucceſſive growth.

Some plants however, take more into their compoſition than others, *e. g.* Agaricus *quercus*, —A. *antiquus*,—Boletus *verſicolor*,—B. *igniarius*,—B. *ſtriatus*,—B. *perrennis*,—Clavaria *hypoxylon*,—C. *piſtillaris*, *&c.*; all theſe contain, from the reſults of analyſis, a quantity almoſt equal to all their other component parts; but others; as Lichen *criſpus*, *pinaſter*, *granulatus*, —Agaricus *piperatus*—Clavaria *aurea*,—Peziza *agaricus*, Lycoperdon *teſſellatum*, contain a very ſmall portion of carbon.

Carbon is obtained from plants in its moſt ſimple ſtate by heat; namely, in expoſing vegetable ſubſtances, excluded from the acceſs of pure air, to ſuch a degree of heat as to ſeparate all the volatile ſubſtances with which carbon is combined; in which caſe, all that adheres then to the remaining carbon may be a few earthy or fixed ſaline particles, which may be ſeparated from the carbon by water and acids.

From ſome experiments it appears, that carbon in that ſtate retains a certain portion of water, and according to Dr. Bancroft, alſo a portion of oxygen which cauſes its black colour. When, therefore, carbon in that ſtate, is expoſed in a cloſe veſſel, and a great degree of heat applied, that portion of water may then be decompoſed, and thus yield hydrogen gas, and likewiſe fixed air according to the new theory.

Carbon obtained from vegetables in the abovementioned proceſs, is a black, light, opaque, matter, which is inſoluble in water, and as far as we know in any other fluid which does not enter into a new combination with it; it is further indeſtructible by the mere effect of heat, and is not inflammable when excited by heat and light alone.

But, it has an attraction for combination with other matters; as for inſtance, for oxygen aſſiſted by heat; in combination with which, it produces the carbonic acid; and that, by the additional combination of ſenſible heat, produces that elaſtic fluid called fixable air or carbonic acid gas, which is the general reſult of the combuſtion of inflammable ſubſtances which contain carbon in their compoſition. In this ſtate of combination it is abſorbable by water, and thereby rendered fit to enter the conſtitution of plants. For the knowledge of the properties of that combination, we are indebted likewiſe to the great Dr. Black.

It appears, from the reſults of ſome experiments, that carbon is a compound; and ſome are of opinion, that it conſiſts of hydrogen and the azotic principle; this ſuppoſition certainly deſerves the attention of chemiſts, as in that caſe, we might be able to explain the formation of carbonaceous matter in plants growing in a ſituation merely ſurrounded by ſand, water, and atmoſpheric air, in which no carbon has been diſcovered; for even then, plants in the courſe of their growth obtain a great portion of that matter, in which caſe the water may be ſuppoſed to afford the hydrogen, and the atmoſphere the azotic principle.

The editor of this eſſay, intends to enquire by experiment into the truth of this opinion, by expoſing a plant to mere water and a ſufficient quantity of atmoſpheric air free from carbonic acid, in order to find, whether, in the courſe of the growth of the plant, the quantity of azote is greatly diminiſhed; and alſo to examine what quantity of carbonaceous matter the plant may then contain in its compoſition; in this experiment, it can eaſily be contrived to give an additional ſupply of oxygen gas if neceſſary.

However, as it is, carbon may be uſeful in many reſpects in promoting the growth of plants. In the ſtate of carbonic acid, it may ſerve as a ſtimulus, or as a ſupply to plants: In its other ſtate, it may ſerve for ſeparating the oxygen from ſuch combinations as ſurround plants, and which may have a noxious effect upon them; or it may promote the diſſolution of old, and the formation of new, combinations.

In the mixture of carbonic acid and heat, as fixable air, on entering the reſpiratory organs of living bodies, it ſoon extinguiſhes life; but, when introduced into the other parts of living bodies deſtined for digeſtion, &c. it diſcovers beneficial qualities.

The noxious quality of fixed air upon reſpiration and combuſtion, is however happily modified or prevented by one of its other qualities, and by the properties of other ſubſtances; in the firſt place, it is heavier than atmoſpheric air, and conſequently, it occupies (when formed and ſet at liberty,) the lower region of the atmoſphere, and cannot thus exert its hurtful quality in that part of the atmoſphere from which our reſpiratory organs receive their food, and from whence combuſtion is ſupplied; ſecondly, it is abſorbable by water and different earths, by which it is therefore taken up and afterwards conveyed to thoſe parts of plants, upon which it induces a beneficial quality.

THE earthy and ſaline particles, which are occaſionally found in the analyſis of plants, ſeem not to be peculiar to their compoſition; as there are plants, in which we ſcarcely diſcover any, and others again which contain a great quantity of them: So for inſtance, earth is found in a great proportion, in hypnum *criſta caſtrenſis*, and neckera *dentroides*; and Mr. Humbold found by an analyſis, that the chara *vulgaris*

vulgaris, contained about $\frac{1}{5}$ of calcareous matter.

Earths probably enter plants, in a ſtate prepared by carbonic acid and diſſolved in water; in this ſtate, earth may part again with the carbonic acid, by a new combination with the acid formed in vegetables, and may thus produce the vegetable ſelenite which is found in plants. Earths in which plants grow, may become very uſeful to them in many reſpects: As for inſtance, by attracting and abſorbing moiſture or other nouriſhing effluvia from the ſurrounding atmoſphere, and communicating ſuch to the proper parts or organs of plants in a due proportion, according as they may require it in the different periods of their growth: Farther, by imbibing the matter ſecreted by the roots of plants, which might become hurtful either to themſelves, or to thoſe growing near them; by abſorbing and retaining the hurtful part of ſome of their applied food, or other deſtructive matter which their decompoſition may produce.

Earth is likewiſe uſeful to plants, in preventing by its coheſive power a too rapid extenſion of their roots, ſo that theſe may acquire a proper firmneſs, both to ſuſtain the different effects induced upon them by their ſurrounding medium, and to prevent, by its interpoſition, a too ſudden effect upon them.

Earths have alſo the quality of imbibing ſuch matter from the ambient atmoſphere, as fixed air, which may become noxious to the different parts in the atmoſphere.

Earths or ſoils become beneficial to vegetation, by their property of imbibing light falling upon them, by which ſenſible heat is produced, which heat occaſions a moderate evaporation of humidity, and diſpoſes ſuch to enter the plants. This evaporation is attended with the production of a moderate degree of electricity, likewiſe uſeful to vegetation; and laſtly, the heat thereby produced, becomes active in promoting a gradual diſſolution and preparation of their applied food, &c. Vide Article HEAT.

Other ſubſtances, as ſaline bodies, may be uſeful in promoting the growth of plants, by acting as a ſtimulus upon them when they are exhauſted, or when they are too much excluded from the other general agents which excite and ſupport their irritability, or may become a ſubſtitute of the abſorbent earth, or modify a too ſtrong coheſion of certain ſoils: As for inſtance, the muriates and nitrates of alkaline ſubſtances, ſelenites, &c.

AMONGST all the above-mentioned ſubſtances which are neceſſary for vegetation, we find water, in its fluid ſtate and of a moderate temperature, is certainly the moſt eſſential ſubſtance; and not only, that its component parts enter into the compoſition of plants and their products, but that it likewiſe enters the veſſels of plants in an undecompoſed ſtate, extends them, modifies the heat, conveys their various foods to their different parts, and gives fluidity to the component parts of their juices, and thereby renders them more fit for circulation. It refreſhes exhauſted plants, acting as a ſtimulus; and laſtly, it diſpoſes the ſubſtances intended for their food to diſſolution, as it is neceſſary, for fermentation, or putrefaction.

PLANTS.

PLANTS, placed immediately after animals, conſtitute the ſecond claſs of organized bodies.

The more we inquire into the economy of plants, the more we diſcover a ſimilarity between them and animals. Plants live; they originate from bodies of their own kind in an uninterrupted ſucceſſion; they aſſume various forms ſucceſſively, from the firſt moment of their exiſtence and life, till their final decay; they contribute to their own growth and preſervation, by receiving foreign ſubſtances into their bodies through their veſſels or organs. Theſe received ſubſtances are changed by the peculiar internal operations of the plants, and are therein prepared, partly, to enter into their proper conſtitution, and partly, for the purpoſe of the formation

mation of their products, which become thereby different from the component parts of the plants themſelves, and different alſo from the nature of the ſubſtances which they had received from without. Plants die, that is, their organs are deprived of the power of receiving food, and of preparing it for their further exiſtence.

Plants like animals, experience three different periods in the courſe of their exiſtence;—*viz.*—origin or beginning,—formation,—and death.

Death is attended with a decay of bodies, and this again with a ſeparation, diſſolution, and decompoſition of their conſtituent parts; which thus follow the laws of chemical attraction and combination.

The living body is indued with a peculiar internal power, which occaſions a diſſolution of the attraction of chemical combination, and which prevents the principles of bodies from acting upon, and from combining with each other,

ther, according to the law of chemical attraction.

The ſubſtances of which organized bodies are compoſed and conſtructed, when theſe bodies are living, follow the laws of their natural impulſe of figuration, (*niſus formativus* of Blumenbach), which impulſe exiſts in all organized bodies, and cauſes each of them to aſſume and preſerve their peculiar ſhapes.

The diſtinguiſhing marks for the two general claſſes of organized bodies, are derived,

1*ſt*, From their organs or parts for receiving food.

2*d*, From motion.

(*Blumenbach, Hanbuch der Naturgeſch.* §. 3. 4. & 170.)

All bodies which receive their food through more than one channel or mouth, and which are deſtitute of the power of a voluntary extenſion and contraction of parts, are arranged under the diviſion of plants.

Life ſignifies the uninterrupted motion of organized bodies.

In plants we obſerve,

1ſt, An uninterrupted motion which is cauſed,

a. By the vital power.

b. By external ſtimulus.

2d, Uninterrupted motion, occaſioned by an internal ſtimulus; as for inſtance, the motion of the *ſtamina* towards the *ſtigma*, and the receſſion from the *ſtigma* before and after impregnation in the parnaſſia *paluſtris*, *&c.*—Vide Mr. Humbold's obſervations on the ſtamina of the parnaſſia *paluſtris* in *Uſters Annales* of botany, N°. 3.

Another example of the ſame nature, and which will be referred to when treating on the irritability of plants, is, that moſt of the water plants riſe or move to the ſurface of the water when about to bloom, and ſo ſink, or are immerſed again, as ſoon as they are impregnated; ſuch we obſerve in valiſneria;

the female flower of this plant is fixed upon a long ſpiral ſtalk, when the time of the bloſſoming approaches, the ſtalk unwinds, and raiſes the flower above the ſurface of the water; the male plant produces a number of flower buds under the water, theſe grow upon ſhort and ſtraight ſtalks, but when about to blow, they ſeparate or detach themſelves from the ſtalks, and rise to the ſurface of the water, where they ſwim and burſt or unfold, and then impregnate the female flower; which, after the impregnation, returns again under the water.

3*d*, Interrupted motion occaſioned by external ſtimulus; as for inſtance, in the mimoſa *pudica*, dionæa *muſcipula*, oxalis *ſenſitiva*, &c.

In the ſtricteſt ſenſe, vital power is the cauſe of all motion, it only manifeſts itſelf variouſly, according as it is excited, or brought into activity, by external or internal ſtimulus, or by mechanical powers.

Though plants generally ſeem not to be capable of moving from their ſituation, or to be ſtationary,

tionary, yet there are exceptions; as, for inſtance, the *lemna,* which changes its ſtation.

Like plants, there are alſo animals, as the lepus *balanus*, aſtrea *edulis*, and lernæa, which are incapable of changing their ſituation; hence, the capacity of organized bodies, of changing the ſtation, is not peculiar to animals alone.

If we take it in the ſtricteſt ſenſe, we may appropriate a moving power to ſeveral plants; as ajuga *reptans*, glecoma *bederacea*, and cuſcuta *europæa*.

There are many inſtances in which animals reſemble plants; as, for inſtance, we obſerve that many inſects begin and finiſh their courſe of life with the cloſe of one ſummer, like the annual plants. As to the propagation of ſeparated parts of plants, we obſerve ſimilar inſtances in parts ſeparated from animals, as polyps, and other aquatic animals.

Uninterrupted motion, we conſider as a doubtleſs characteriſtical mark of living bodies. This we obſerve in animals and plants; both diſcover more activity in the ſpring than in winter.

The total interruption or ſuſpenſion of life cauſes death. Though the motion of many plants is ſcarcely, or often not at all perceptible in the winter ſeaſon; yet it would be contrary to all experience, to ſuppoſe that plants ſhould then ceaſe to live, if nothing elſe has occaſioned their deſtruction.

We know that plants, like animals, receive and excite matter of heat, and that both manifeſt ſenſible heat. Later diſcoveries have alſo proved, that plants emit or yield matter of heat even in the winter ſeaſon.

The moiſt atmoſphere which we perceive in the ſhade under trees, probably originates, not merely from their being excluded from the light of the ſun, but becauſe the trees attract and imbibe a great portion of matter of heat, by which the water thereby held in the atmoſphere is deprived of its elaſticity, and is thus made to ſeparate in the ſtate of moiſture.

Plants may receive heat from the ſurrounding atmoſphere, by imbibing the air, and partly decompoſing it, and alſo from their food during the digeſtion. Buffon and Hunter have proved the fact, that plants have a power of producing ſenſible heat.

THOUGH plants receive their food through various canals or mouths, and do not collect them in one reſervoir like animals; yet, the mode and effect of their digeſtion reſembles much that of animals. They part like animals, with the ſuperfluous and uſeleſs matter; and this ſeparation they effectuate, not only by their reſpiratory organs, the leaves and ſtems, but alſo by other ſecretions ſimilar to what we obſerve in animals.

Mr. Humbold, a gentleman of great reputation among the learned in Germany, has obſerved, that plants really ſecrete impurities through the extremities of their roots during the night, which excrements may, like thoſe of thoſe of animals, prove ſometimes uſeful, ſometimes hurtful, to other neighbouring plants. "Sic "læditur," ſays he, "avena a ſerratula *arvenſi*, "triticum ab erigero *acri*, linum ab euphorbia "*peplo* et ſcabioſa *arvenſi*, polygonum *fagopy-* "*rum*, a ſpergula *arvenſi*, *&c.*" From this he derives the effect of fallowing, and the harmony among plants.

It is a well known fact, that ſome trees will not grow well near others, or that the one is hurt or ſuppreſſed by another of a different kind. The cauſe of this was thus explained, that the one deprived the other of its neceſſary portion of food; but Mr. Uſlar ſuppoſes, with much plauſibility, that the ſecreted matter of one kind of plants or trees, may likewiſe add to the cauſe of the deſtruction or injury of others. There are plants which do not allow others to grow near them, and which ſeem to prefer a ſolitary life. This circumſtance has given riſe to a diviſion of plants, into SOCIATÆ and SOLITARIÆ. Similar antipathy we obſerve likewiſe among animals; as certain different genera of animals will not live together in harmony.

Mr. Uſlar is opinion, that this partly ariſes from phyſical cauſes; as he obſerved, that certain animals cannot bear the effluvia of others.

Though certain plants ſhow a great antipathy to one another, yet there are ſome which aſſiſt the growth of others. So, for inſtance, we find the birch often nouriſhing the oak and the beech.

Plants and animals perſpire liquid and permanent elaſtic fluids. The exhalation from certain parts of animals varies reſpecting the quantity and compoſition of the matter perſpired; the ſame we obſerve reſpecting plants.

The cauſe why certain parts of plants produce conſtantly the ſame juices and exhalations, lies probably in the peculiarity of ſtructure of the organs, diſpoſed in the various parts of living plants.

With reſpect to propagation, we obſerve again a ſimilarity in both claſſes of organized bodies, in the more natural mode of propagation, and in the production of mules or hybrids.

With reſpect to the production of hybrids, the following laws are common to both:

1ſt, Only ſuch plants and animals are miſcible, as have natural affinity to each other; hence, neither hens and rabbits, nor oaks and pines are miſcible.

The affinity of plants is not always to be determined by their external form; not unfrequently we muſt aſcertain it by the ſimilarity of their pollen.

2d, The hybrid approaches always to the male, in the ſubſequent generation. In regard to the parts of generation, we obſerve great differences between animals and plants; thoſe of the former are permanent, and thoſe of the latter are reproduced for every ſucceſſive generation.

How nearly plants approach to animals reſpecting their copulation, &c; we may ſee from the obſervations contained in the valuable diſſertations of the great HEDWIG, *viz.* his Hiſtory of Moſſes, and Account of the Fructification of the Cryptogamic Plants.

Winter ſleep or reſt, is common to animals and plants; during this time the action of their organs does not ceaſe, it is only modified.

To the analogy between plants and animals, we may add the power of reproduction.

a. Reproduction of parts loſt by the natural diſpoſition which is common to both; *viz.* in animals, the fall and reproduction of hairs, feathers, and horns, in the autumn and ſpring; in plants, the ſeparation and reproduction of the cuticle and leaves.

b. The reproduction of parts accidentally deſtroyed, to which we refer the conſolidation of wounds.

The cauſe of reproduction was generally attributed to the preſence of a number of original embryos, exiſting or previouſly diſperſed through the body, and which are occaſionally evolved, if there be a ſufficient ſupply of food, &c.

The excellent Phyſiologiſt, Profeſſor Blumenbach of the Univerſity of Gottingen, however, has favoured us with a different and very ingenious theory; according to him, there exiſt no preformed embryos in organized bodies; but he alleges, that in the prior unformed generative matter of organized bodies, after it arrives at maturity, and has reached its fixed and deſtined ſituation, a peculiar and continually acting impulſive force is ſet at liberty, and cauſes this matter to acquire or aſſume a certain form at firſt, and to preſerve the ſame afterwards; ſo, that if ſuch form be injured or loſt, it may be repaired or reproduced. This impulſe or impulſive force is connected with the vital powers, but equally and evidently differs from contractability, irritability, and ſenſibility, as well as from the common phyſical powers of bodies; and it appears to be the firſt, and moſt eſſential inſtinctive power neceſſary for generation, conſervation, and reproduction.

OF THE

NISUS FORMATIVUS OF BLUMENBACH *.

THERE are two theories known of generation and reproduction. The one is diſtinguiſhed by the name of Epigeneſis; by this it is maintained, that when the mature, but crude and unformed generative matter of the parents, reaches the place deſtined for its reception, at the proper time, and under the neceſſary circumſtances, it is then gradually formed into a creature.

The other theory is diſtinguiſhed by that of Evolution. This theory denies all generation of the organized world; it contends, that nature had at once produced the embryos for all animals

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* Vide his treatiſe on that ſubject.

animals and vegetables, which ever have lived, and which ever ſhall live, at the firſt creation; ſo that now nothing is neceſſary for the production of theſe, but a ſucceſſive evolution of the embryo. To this theory Mr. Blumenbach makes very ſtrong objections, as may be ſeen in his treatiſe on generation, lately tranſlated into Engliſh by Dr. Crichton of London.

Blumenbach remarks, that many unorganized bodies aſſume a regular form when properly diſpoſed for it, as we obſerve in the cryſtalliſation of ſalts, and various other ſubſtances. Though this power or cauſe is different from the impulſe of figuration of organized bodies; yet it is evident, that there muſt be ſomething which has the power, or which cauſes the ſame bodies to aſſume the ſame regular form under the ſame circumſtances.

In order to perceive the effect of the impulſe of figuration moſt diſtinctly, Dr. Blumenbach choſe ſuch organized bodies for the ſubjects of his obſervations, as have a conſiderable ſize, yet are almoſt tranſparent and grow very faſt. In theſe he was enabled to obſerve even the interior change and operation of their formation, *e. g.* conferva *fontinalis*. This vegetable being is well known to botaniſts; it conſiſts of a ſingle, almoſt ſtraight, ſhort, and ſlender thread; the fine hair-like matter which we obſerve in the ſpring in wells, &c. conſiſts of a great number of theſe plants, which have ſhot forth and fixed their roots in the mud.

The propagation of this plant thus proceeds; the extremities of the threads ſwell, and form ſmall tubera or heads, which gradually ſeparate from the mother threads, and attaching themſelves to ſome particular ſpot, they grow in a ſhort time to a perfect thread. The whole progreſs of their formation can be obſerved in the courſe of 48 hours.

Dr. Blumenbach could not diſcover, by the aid of the beſt magnifying glaſſes, any trace of an involved embryo, &c.; he made alſo ſimimilar obſervations on a certain kind of polyp.

The reſult of his obſervation was, that;

1*ſt*, The impulſe of figuration proceeds rapidly in early life, ſlowly and more perfectly in advanced age.

a. By the generation of the foetus;

b. By the reproduction of parts on the formed bodies of plants and animals.

2*d*, The power of figurative impulſe varies;

a. In various parts of the body;

b. In different bodies.

In like manner, we obſerve diverſity reſpecting irritability in certain parts of plants hereafter to be treated of.

3*d*, The impulſe of figuration, or *Niſus Formativus*, takes ſometimes a preternatural direction; in which caſe there are produced,

a. Heterogeneous forms, as horns and hairs; or, in plants, we obſerve leaves reſembling thoſe of a different ſpecies.

b. Preternatural forms, as monſters.

The cauſe of ſuch deviation we cannot inveſtigate. Inſtances of it more rarely occur, however, in wild and unconfined animals, and more frequently in ſuch as are confined or domeſticated; for climate and food, both ſeem to have great influence in cauſing ſuch deviations.

ORGANIZED BODIES CONSIST;

1*ſt*, OF ſolids;
2*d*, Of fluids.
The latter are,
  a. Liquid; or,
  b. Permanently elaſtic fluids.

Carbon, hydrogen, azotic principle, and oxygen, are the chief principles of plants.

The ſolid maſs of ſuch bodies is partly organized, partly deſtitute of organization.

Every living creature is provided with various veſſels and inſtruments, neceſſary for its propagation, preſervation, and for promoting its periodical growth; theſe conſtitute its organized part.

The organs of animals and vegetables have, or aſſume, a determined ſtructure, which does not depend on accidental cauſes.

The ſolid parts of plants Mr. Uſlar divides into,

1*ſt*, Primitive ſolid fibres, which he calls *faſern;*

2*d*, Simple fibres.

By primitive fibre *(faſer)*, he means the unorganized matter; it is the whole corpuſcular maſs, which poſſeſſes the vital power only when in connection with the organized parts; the uſe of it is, to connect the ſmalleſt fibres, and thoſe veſſels which are more or leſs compoſed of them, to cover them, and to fill up their interſtices.

The whole unorganized maſs Mr. Uſlar calls cellular web; what **Bordeu** calls *tiſſu muqueux.*

All ſolid parts of plants are formed of one and the ſame matter, Cellular Matter. This probably originates from gelatinous juices, in combination with other principles; by the acquirement of it, all forms are generated; hence the appearance of organization, in unorganized parts.

The ſimple parts of the organized maſs conſiſt of fibres. "Solidarum partium in animalibus et vegetabilibus communis eſt ea fabrica, "ut earum elementa, quæ ſubtiliſſima micro-"ſcopium attingit, fibræ ſint.—Haller."

Fibres, as far as we have been able to diſcover their moſt ſimple ſtate, are thin cylindrical lines; their matter is cellular web.

The ſolidity of the fibres, as well as that of the whole organization, depends on the denſity of the cellular web, that being the matter of which they were formed; and the denſity of the cellular web, depends upon the cloſe, or looſe condition of the imaginary ſimple fibres of which that is again compoſed, as well as from the intimate connection of thoſe parts among themſelves.

By the combination of fibres veſſels are formed; this is the ſecond ſtep of organization. The third ſtep conſiſts in the connection of certain veſſels, of which compound organs or inſtruments are formed. It appears, that a very intimate combination among the organs of organized bodies takes place; elſe conſiderable injuries of parts of plants would immediately cauſe their deſtruction or death; which, however, is ſeldom the caſe. According to Mr. Uſlar's opinion, the combination of fibres, veſſels, and inſtruments, is produced,

a. Directly by the unorganized maſs.

b. By the interweaving of very minute branches, whoſe extremities terminate in open mouths.

Simple as the ſtructure of plants and their organization appears, yet we obſerve a great complication in the connection or compoſition of the fibres of the cellular web. This has been ſufficiently obſerved and ſhown by phyſiologiſts; and any body may eaſily convince himſelf, by the aid of a magnifying glaſs, that each genus and ſpecies of plants has ſomething peculiar in the connection of the fibres of the cellular web; and that the proportion of the veſſels varies as to ſize and number; it hence naturally follows, that the preparation of the received alimentary juice muſt thereby be variouſly altered or modified; and thence the great variety among vegetables may originate.

In the animal body we diſcover two different kind of fibres,

1ſt, The ſenſible or nervous fibres; of which the nerves of animals are compoſed. We ſhall hereafter obſerve, that ſenſation depends on nerves, a property of which plants are deſtitute, according to the general opinion. In ſo far as we underſtand by ſenſation, the perception

tion of external things, and the ſuſceptibility of pleaſant and diſagreeable impreſſions, we may conſider plants to be deſtitute of that ſenſation.

Animals poſſeſs the property of ſenſation in very different degrees. In many of them we diſcover it in a very inferior degree; ſo that the motion by which it becomes manifeſt, appears to reſult merely from a ſtimulus acting directly upon the irritable fibre, like what we obſerve in plants.

Mr. Uſlar does not chooſe to compare this to the motion which is cauſed by the irritability of plants, though ſomething might be deduced from it, which may ſhow the cloſe analogy between the inferior tribes of animals and plants. The nervous fibre has not yet been diſcovered in plants; and the want of ſenſation, taken in the ſtricteſt ſenſe, affords already the analogical concluſion of the abſence of this fibre.

2*d*, Another kind of a fibre, totally different from the foregoing, is the muſcular fibre, *(fibra irritabilis.)* This is common in all organized bodies. It exiſts in plants as well as in animals. It not only cauſes the motion; but it is alſo the material cauſe of life, in ſo far as we conſider irritability as a vital principle of organized bodies.

The power of contraction, in organized bodies, depends on the irritability of the muſcular fibre; that wherever, therefore, we obſerve a contraction of the parts to which a ſtimulus is applied, we may ſafely conclude the preſence of muſcular fibre in theſe parts. Haller ſays, that, in many caſes, we diſcover the exiſtence of muſcular fibre in certain parts, more by its effect, than by our organs of viſion.

If the cauſe of contraction, obſerved after applied ſtimulus, lies in the irritability; and if it is true, as it really appears to be, that only the muſcular fibre poſſeſſes irritability; it is then not difficult to prove the exiſtence of irritable fibres in plants; by viſible perceptions.

It

It is well known, that the leaves, ſtalks, and ſtamina, of many plants manifeſt irritability, or contract when touched; *e. g.* the leaves of droſera *longifolia*, droſera *rotundifolia*, dionæa *muſcipula*, averrhoa *carambola*, mimoſa, &c. the ſtamina of the cactus *opuntia*, and ſeveral other ſpecies of that genus, the ſtamina of berberis *vulgaris*, heliotropium, parietaria *officinalis*, lilium *ſuperbum*, calendula, martynia *annua*, and ſeveral of the urtica genus, as, for inſtance, urtica *dioica*. On this ſubject we have a valuable diſſertation by Mr. Medicus, Prime Counſellor, &c. Of the Inſtinct of Plants for copulation, in Hiſt. et Comment. Acad. Theod. Palat. Tom. III. pag. 116, *et ſeq.* and alſo by Des Fontaines, on the irritability of plants in general, Bonnet, Brouſſonet, Hope in Diſſert. quædam de Plantarum Motibus et Vita complectens, Edin. 1787; and Gmelin de Irritabilitate Plantarum.

This may ſuffice, for the preſent, to prove the exiſtence of irritable fibre in plants, or in all organized bodies; more will be ſaid upon this ſubject in treating of irritability, in particular examples.

Mr. Gritanner, by his experiments, endeavours to prove the exiſtence of three different kinds of irritable fibres.

1*ſt*, The Straight Fibre *(recta)*, which contracts longitudinally, or in ſuch a manner, that the extremities approach each other.

2*d*, The Spiral Fibre *(ſpiralis)*, by the contraction of which the diameter of the veſſels which are formed by it is diminiſhed.

3*d*, The Circular Fibre *(circularis)*, generally diſcovered at the extremities of veſſels; the apertures of which it cloſes by its contraction.

The contractility of the irritable fibre manifeſts itſelf after an applied ſtimulus. But there is a difference in the effect of the contraction, according to the different external form of the fibre; and alſo, with reſpect to the velocity with which the ſtimulus is received. The contraction of the ſtraight fibre takes place quickly, or even inſtantly throughout the whole fibre, as ſoon as one of its parts receives the ſtimulus; from which it may be concluded, that theſe ſtraight fibres exiſt particularly in thoſe parts of plants, the contraction of which takes place immediately and perfectly; as, for inſtance, the leaves of dionæa *muſcipula*, and mimoſa *pudica*. The contraction of the circular fibre takes place more ſlowly and gradually; that of the ſpiral fibre is ſloweſt of any. The ſtimulus which is quickly communicated from every part of the ſtraight fibre to the others, proceeds but ſlowly in the circular and ſpiral fibres; it is communicated ſucceſſively to their different parts; and manifeſts correſponding effects. This contraction of the ſpiral fibre has been called Periſtaltic Motion; and Malpighi was perhaps the firſt who diſcovered it in the ſpiral veſſels ſeparated from the ſtem; it is likewiſe found in the inteſtines of animals.

THE VESSELS AND INSTRUMENTS, OR ORGANS OF PLANTS, MAY BE DIVIDED INTO;

1ſt, ORGANS for ſecretion ;

2d, Organs of motion.

Farther, according to HEDWIG, with regard to the direction in which they move their contained juices.

a. Either from the ſtem towards the branches, *(adducentia.)*

b. Or from the branches towards the ſtem and roots, *(revehentia.)*

Moreover, the organs of plants may be divided into thoſe which ;

1ſt, Serve for the continuation and preſervation of life ;

2d, Effectuate the propagation and generation of the germs of new bodies of the ſame kind.

For this purpoſe it appears, that all the organs and ſingle fibres harmoniouſly unite their powers. Harmony manifeſtly exiſts in the whole creation; by it all nature is concatenated; the more therefore may we preſuppoſe it in the ſtructure of any ſingle body.

In the more particular diſcrimination of the various veſſels, Mr. Uſlar follows the famous Mr. Batſch; he conſiders them as,

1ſt, Filamentous.

- *a.* Utricles, *(utriculi)*, which are produced or adhere horizontally;
- *b.* Succiferous, or ſap-veſſels *(vaſa ſuccoſa)*, which proceed longitudinally in plants; theſe may be divided into,
  - *a.* Pith-veſſels, (*vaſa medullaria*), which are chiefly found in the medulla;
  - *b.* Nutricious-veſſels, *(vaſa propria, nutrientia;)*

c. Lymphatic-veſſels, *(lymphatica.)*

2*d*, Spiral veſſels; they conſiſt of flatted fibres or threads, of an equal breadth, which are wound or coiled up in a ſpiral manner, ſo as to form a tube; *(tracheæ, vaſa aërea* or *ſpiralia).*

Meſſrs. Grew and Reichel conſider them, contrary to Malpighi's opinion, as conſiſting of ſeveral fibres, whereas the latter conſiders them as made up of a ſingle fibre.

They are found for the moſt part underneath the bark, and frequently under the cuticle of ſuch plants as have no proper cortical ſtrata; as, for inſtance, the graſſes; they are very irritable, and contract by an applied ſtimulus.

Malpighi repreſents, that theſe veſſels are conſtantly filled with air, and that they reſemble the tracheæ, or air-veſſels of inſects; Mr. Grew, on the contrary, aſſerts, that they contain occaſionally different juices. Their great uſe is to ſerve as reſervoirs for air; but modern phyſiologiſts aſcribe ſome other qualities to them:

Linné thought that he had diſcovered the living power of plants to reſide in the medulla or pith, and that the production of the corculum or rudiment of new plants was derived from it; this however, at preſent is believed to be produced by the *fiſtulæ ſpirales* *.

The before-mentioned ſuppoſition ſeems to be very probable; for how ſhould it be poſſible, that plants, or hollow trees, which have loſt the greateſt part of their pith or medulla, as we frequently obſerve on the old ſtems of willows, &c. ſhould be able to produce new parts, *e. g.* buds, and ſeeds, and ſhould continue to grow as vigorouſly as if they contained all their pith.

The claſſical writers on this ſubject are; MALPIGHI, GREW, in the Anatomy of Plants: BONNET,

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* The neceſſity and efficacy of theſe ſpiral veſſels, is ſufficiently and ingeniouſly demonſtrated by HEDWIG, in a diſſertation on the Origin of the Male Parts of Fructification of Plants; and likewiſe, in another, in which he has anſwered the queſtion; What is properly the Root of Plants?

NET, *Recherches ſur l'Uſage des Feuilles dans les Plants:* BAISSE *de Vaſis Plantarum.* In which Jampert's opinion, againſt the probability of the exiſtence of veſſels in plants, is refuted.

Indeed, natural appearances, and the reſults of many microſcopical examinations, ſeem to prove ſufficiently, that plants have veſſels.

The UTRICLES ſeem to be intended for containing the juice or ſap, and probably likewiſe for aſſiſting in the preparation of it. The formation of the vegetable juice is too ſubtile an operation to be demonſtrated or imitated by chemiſtry. For, notwithſtanding the many opinions which have been ſuggeſted reſpecting the interior oeconomy of plants, we are ſtill much in the dark with regard to it; we know little of the more minute combinations and ſtructure of organized bodies, but ſtill leſs do we know of their internal operations.

We may ſuppoſe, that plants like animals have,

1ſt, Common juices, which are diffuſed through all parts of their body.

2d, Particular juices, which are found only in certain parts, and are probably ſecreted from the firſt. They are contained therefore in particular ſecretory veſſels. One part of the juice thickens, from time to time adheres to the ſolid fibre *(faſer)* of the cellular web, increaſes thereby the maſs, and thus promotes growth. In this manner the origin and formation of new ligneous fibres may be explained.

In order to underſtand how the nutritious liquid received by plants, and the juices ſecreted by them, can appear in ſuch different forms or ſtates; as a ſolid body in the woody plants; as a compact inflammable matter; and how the aqueous liquid is changed into vegetable juices; recourſe muſt be had to the firſt part of this treatiſe.

We know, that bodies may aſſume various ſtates; they may paſs from a ſolid to a liquid, and from a liquid to an elaſtic fluid ſtate, ſolely by means of heat.

The nutritious water in plants may change its liquid ſtate to an elaſtic fluid, in two ways;

a. By the accumulation of heat; or,

b. By decompoſition.

By decompoſition, the two conſtituent parts, the oxygen and hydrogen, are ſeparated from each other. The hydrogen enters into a new combination with the vegetable matter; the oxygen is ſet at liberty, and eſcapes in the ſtate of oxygen gas by means of light. Light acts, partly as a ſtimulus upon the leaves and upon the green coats of the tender ſtems, partly as a matter having a ſtrong attraction for the oxygen, and thereby effectuates the formation, and ſubſequent eſcape of the oxygen gas.

All elaſtic fluids are condenſible; the hydrogen appears to exiſt combined in plants in a ſtate of condenſation. Hydrogen, or hydrogen gas, is, as we know, inflammable; and by its combination with oxygen gas flame and ſenſible heat are produced; the latent heat of theſe fluids being diſengaged in conſequence of the greater attraction of the oxygen for hydrogen.

Newton's ſuppoſition, that water is a body, intermediate between an inflammable and non-inflammable ſubſtance; that water is neceſſary for vegetation; and that plants receive their inflammable matter from it, is now verified by experiments and facts. By the diſcovery of the compoſition and decompoſition of water, much light has been thrown upon the nature of plants. Another portion of their inflammable matter, plants may obtain from the atmoſphere, by the abſorption of air and effluvia therein contained.

The matter with which the hydrogen, when ſeparated by the decompoſition of water, is combined again in plants, ſeems to be carbon. A great quantity of carbonic acid gas is conſtantly produced by the reſpiration of animals,

mals, by fermentation, by various decompoſitions, and by the combuſtion of vegetable ſubſtances.

There are even plants which emit carbonic acid gas, *viz.* ſalix *viminalis*, pinus *cedrus*, quercus *robur*, betula *alba*. We know, as obſerved before, that this gas is ſpecifically heavier than atmoſpheric air, in conſequence of which it ſinks towards the ſurface of the earth, which it gradually enters; it is then conveyed to the roots of plants, and thus becomes beneficial to them. It appears, that plants receive and have the power of decompoſing carbonic acid gas in like manner, as they receive and decompoſe water.

The following ſimple experiment will ſuffice to ſupport this opinion.

Plants yield oxygenous gas when expoſed in the ſun: If two branches of a plant are immerſed, the one in common water, and the other in water impregnated with fixable air or carbonic acid; we then find, that the branch immerſed in the latter liquid, yields, under the ſame circumſtances, a greater quantity of oxygenous gas than the other. The difference in ſome experiments has been found in the proportion of 264 to 1. The proportions vary however, when different plants are ſubjected to trial, ſo much, that no general law can be eſtabliſhed. The carbonic acid, with which the water is impregnated, is decompoſed then by the branch, the carbon enters ſeemingly into the conſtitution of the plant, while the oxygen is ſet at liberty, and flies off, more or leſs of it, in the ſtate of gas.

Plants do not, however, retain all the carbonaceous matter which they receive; they obtain more in the courſe of the day when acted upon by light, than they naturally require. By the abſence of light, plants loſe part of this carbon, as during the night; hence, the cauſe, that plants yield reſpirable gas only in the day-time, particularly when the ſun beams fall immediately upon them; and that plants do not yield pure air in the night, but frequently at that time give out bad air.

That water, or its component parts, afford the principal aliment for plants, not only appears from their quick growth after an electrical rain, but alſo, by the quick formation and growth of many fungi, *viz.* clavaria *faſtigiata*, agaricus *campeſtris*, &c. The opinion, that theſe fungi were formed by fermentation and cryſtaliſation from the mucilage of other vegetables, is ſufficiently refuted by the ingenious Mr. Wildeno. Later diſcoveries in chemiſtry, have enabled us now to underſtand the various combinations and decompoſitions which may take place of ſubſtances which enter plants; that the more ſimple ſubſtances not only may aſſume different forms, but that they may change likewiſe their properties when combined with each other in various proportions, has been explained in the former part of this treatiſe.

OF THE SUCCESSIVE INDURATION OF CERTAIN ORGANS OF PLANTS, OR THEIR CHANGE INTO WOOD, AND OF THE DIFFERENCE AMONG PLANTS.

FROM the phyſiology of animals, we know, that;

1ſt, The living body in its infancy, conſiſts of more ſucculent parts than in older age, and that the ſolid parts increaſe with every year in the courſe of life, to a certain period, when they attain their perfect ſtate.

2dly, That, by the conſtant exertion, many organs are weakened or become leſs active; many parts are condenſed by preſſure, as well as by attraction of coheſion. Some of the ſmall veſſels loſe thereby the capacity of tranſmitting the juices, others are deprived of their extenſibility; this occaſions the cavities to be filled up, the rarer parts are changed into ſolid web, and by this again many veſſels are cloſed. The irritability is diminiſhed by age, ſome parts are entirely deprived of it, and they remain uncorrupted or alive, only in as far as they are ſtill connected with other ſound and active parts.

Theſe obſervations applied to plants, make it likewiſe comprehenſible, how their organs or parts may be changed into ſolid and woody fibres *(faſern)*.

The reſult of all theſe changes is the death of the parts. The quantity of juice diminiſhes, as parts become more compact and ſolid; the abſorbent veſſels gradually ſuffer; and becoming unfit for their functions, the nouriſhment is thereby diminiſhed.

OBSERVATIONS ON THE IMPORTANT QUESTION, WHAT CAUSES THE GREAT VARIETY OF THE INTERNAL AND EXTENAL CONSTRUCTION OF PLANTS?

1ſt, THE firſt cauſe lies in the organization. The main body or general maſs, we obſerve, has a different ſtructure in different plants. Not only the conſtruction of the ſolid fibre of the unorganized part *(contextus celluloſus)*, varies with reſpect to denſity, &c.; but alſo the form of the organs, of the juice veſicles, &c. the ſtructure of which, and thinneſs of their coat, enables them to ſecrete more or leſs of the elementary conſtituent parts of their nutritious juice in a variety of ways: So that we may almoſt conſider them as inſtruments for chemical operations. We find that ſome are more fit for the ſuſception, rarefaction, and preparation of food, than others. There is no doubt, but that the diſſolution, ſecretion,

cretion, aſſimilation, &c. of the principal conſtituent parts of the nutritious juice, preſuppoſes a variouſly modified, but determinate ſtructure of the different organs.

2*d*, Another cauſe of the variety, lies in the altered ſtate of the received food, and in the different proportion of mixture.

Water and atmoſpheric air are the ſubſtances which afford plants what they principally require for vegetation. Though ſimple theſe ſubſtances appear to be, yet we know, by the aid of chemiſtry, that they are not only compoſed of the moſt efficacious elementary ſubſtances, but alſo that they contain a variety of heterogeneous matters.

Oxygen, hydrogen, and carbon, ſeem to conſtitute the main aliment of plants; a great portion of the two laſt is taken up by the veſſels, and combined in them with the vegetable matter. Earth appears not to be a neceſſary component part of all plants; for by the analyſis of many vegetables, ſuch as the byſſus, peziza, and ſeveral other cryptogamic plants, particularly of the genus of fungi, we find no earth in their mixture; and though there are plants which contain more or leſs earthy parts, particularly calcareous earth, yet this does not prove that earthy parts are neceſſarily component parts of plants.

A great number of experiments, both of earlier and later periods, have ſhown that plants do not immediately obtain the requiſite earthy particles from the ſoil in which they grow, but that they receive ſuch from water and the atmoſphere.

Hales, Bonnet, and others, have aſcertained theſe facts directly by the increaſe of weight; and how would it otherwiſe be poſſible, that an oak could vegetate ten years in water, and its maſs continually increaſe. Nature preſents ſimilar inſtances, and ſhows by paraſitic and pſeudo-paraſitic plants, that the earth or ſoil upon which they grow, does not afford them pabulum, but that they receive their earthy particles by other channels.

We frequently find plants (which Mr. Uſlar calls Pſeudo-Paraſitic plants), upon ſteril and naked rocks, upon walls, &c. *viz.* rubus *idæus*, vaccinium *vitis idæa*, rubus *fruticoſus*, which by accident are often found upon the ſtems of old decayed trees, and continue there their growth.

Mr Uſlar found that plants would grow in mere pounded quartz; not only herbaceous plants, as lepidium *ſativum*, or reſeda *odorata;* but alſo ſhrubs, the heliotropium, *e. g.* grew particularly well. The inſoluble particles of quartz could ſerve here as only a fixed place for thoſe plants, and as a reſervoir of the water.

The ſuppoſition, that plants in ſuch caſes were nouriſhed by the heterogeneous, earthy, and ſaline particles contained in the water, and not by the water itſelf, is ſufficiently refuted by Mr. Hoffman; who by very ingenious experiments found, that plants grew in diſtilled water and air; (which are deſcribed in Green's journal.)

This eminent Botaniſt accidentally obſerved, that a plant, mentha *criſpa*, growing in a glaſs with water, had ſhot out roots; this immediately engaged his attention, and led him to the following experiment, he put the ſame branch in diſtilled water, and found that the plant did not only continue alive throughout the winter; but alſo, that in ſpring it began to puſh forth buds, which produced branches, flowers, and ſeeds.

In order to examine the juſtneſs of Mr. Von Beunie's, and Spallanzani's aſſertions; that not only water and fixed air, but alſo ſeveral earths, particularly lime, marle, clay, promote the growth of plants; and that indeed water did not ſo much itſelf aſſiſt vegetation, as the oily and ſaline parts contained in it; Mr. Hoffman employed, in the following experiments, water which had been previouſly freed from all heterogeneous parts by diſtillation.

Having cut off a ſmall branch of mint, weighing one dram and fifty grains, he placed it in a phial containing 8 ounces of diſtilled water, and ſecured the mouth of the phial with a waxy cement, fitted cloſe alſo round the ſtalk, ſo that no water could eſcape at this place, nor any heterogeneous matter get into the phial. The phial with the plant was placed in a large room, and after 10 days, he perceived already ſmall roots ſhooting out from the lower joint of the branch which was immerſed in the water; theſe increaſed in number more and more; after 14 days he cut over the branch above the ſecond joint which was without the phial; the part thus ſeparated weighed 1 dram 15 grains. Three weeks after, new buds began to ſhoot out from this joint, between the two leaves and the ſtalk, and theſe grew out into branches ſimilar in ſize, form, and odour, to thoſe commonly produced on this plant.

After ſix weeks, all the eight ounces of water were conſumed, and the plant had altogether increaſed in weight eight ſcruples, or two drams and forty grains.

The phial was again filled with diſtilled rain water, and the ſame experiment repeated. The evaporation of the water in theſe experiments could only proceed through the plants; the conſumption of the water varied, according to the temperature and the intenſity of the light to which the plant was expoſed, and likewiſe, according to the different ſtate of vegetation; for, in the firſt days, before the buds were apparent, the quantity conſumed was only 10 grains in the ſhade; but, as the growth advanced, the quantity of water conſumed alſo increaſed from 10 grains to ſeveral ſcruples in the ſun, often to two drams. At the approach of autumn, the perſpiration diminiſhed and gradually became imperceptible; at the ſame time, the leaves of the plants became relaxed and loſt their colour. The water then is conſumed only during the growth of the plant; it therefore ſeems probable, that the water in this proceſs has undergone a decompoſition to promote the growth.

The weight of both branches which had been produced in the latter part of the experiment,

ment, amounted to two drams; and nothing but water and air could in this caſe afford pabulum to the plant, or the matter of which its parts were formed. Hence, therefore, the decompoſition of water by vegetation, and the combination of its conſtituent parts with vegetable ſubſtances, may be fairly deduced.

The cauſe why all plants will not grow upon the ſame ground, depends probably on the capacity of the ſoil to receive the food, and to retain it for the proper time.

Succulent plants require generally a moiſt ſoil; ſuch, *e. g.* as ſhall conſiſt chiefly of garden mould, or the earth of decayed vegetables: For this not only imbibes the water eaſily, but likewiſe retains it very long. Such ſoil is, however, often adverſe to the growth of other plants.

That plants receive their food from water, has been alſo lately confirmed by Von Marum; who alſo repeated the obſervation, that plants extend their roots towards moiſture.

Trees growing near the banks of rivers, extend their roots, particularly towards the water; and if a moiſt ſpunge is laid near a ſide root, we obſerve, that the root is attracted, as it were, by the moiſt ſpunge, as iron by a magnet.

Leaves appear to be the moſt neceſſary inſtruments for ſupporting vegetation. They anſwer not only the purpoſe of receiving food, but likewiſe the purpoſe of lungs, for reſpiring and perſpiring air or other elaſtic fluids.

Plants which have a conſiderable foliage, perſpire more than thoſe with few leaves.

If we take two branches, and deprive the one of its leaves, we then find,

1ſt, That that branch which is deſtitute of leaves, does not take up ſo much water as the other which has its foliage entire.

2dly, That the firſt becomes nevertheleſs heavier than the latter, by reaſon that the water which it abſorbs is not decompoſed by it, but remains for the greateſt part within it in an unaltered ſtate: while, on the contrary, the other, though it retain moſt of the hydrogen, retains only a ſmall part of oxygen, emitting the greateſt part of the latter in the ſtate of gas, by the effect of light. Trees, therefore, with much foliage, ſeem to require a more humid ſoil than thoſe with leſs foliage. This is generally indeed obſerved to be the caſe: but there may be now and then exceptions, for ſome plants perſpire leſs than others. The difference ſeems to proceed, partly from their internal ſtructure, according to Mr. Uſlar; becauſe the trees of hot climates, which have much foliage, do not perſpire as much as thoſe of more temperate climates.

A lemon tree, for inſtance, perſpires in proportion leſs than acer pſeudo-platanus or ſycamore.

The external form of the leaves is alſo different and may have effect on the perſpiration. The leaves of the lemon tree are entire and ſmooth; whereas, thoſe of the ſycamore are angular, and their under ſurfaces are covered with fine hairs, which are probably intended for perſpiration.

As the external form of parts aſſiſts perſpiration; in the ſame manner, it appears that the form has influence upon the reception of food from the air; and Mr. Uſlar believes, that the ſituation of the leaves, the direction, circumference, margin, ſurface, promote the one or the other more or leſs: Folia *ſerrata*, inciſa *dentata*, acute *crenata*, &c. all theſe are not only better conductors, but alſo more capable of perſpiration, than ſuch as have a ſmooth or even margin.

Bodies armed with, or ending in ſharp points, not only attract electricity better, but when impregnated with electric matter, they allow it to ſtream out of them with greater velocity than ſmooth or blunt bodies do; and as plants receive, not only elaſtic fluids from the atmoſphere, but alſo electric matter; it may be concluded from analogy, that their form will have likewiſe conſiderable influence on this occaſion.

The great difference among leaves, their different origin, and uſe, &c. is well demonſtrated by Profeſſor Batſch in his book, entitled, Anleitung zur Kentniſs der Pflanzen, §. 87, to 102,

It appears from what has been obſerved, that the aliment which the roots take up from the ſurrounding earth, ſcarcely differs as to quality in different plants; and, that the alteration of it takes place only by peculiar co-operations and modifications within the particular plant: this is obvious in grafted fruit trees, and indeed in others; quercus *ilex*, for inſtance, grafted or innoculated upon quercus *robur*, retains its leaves through the winter in a ſound ſtate like its mother plant.

That there is great variety of organization in plants, and that through various operations thence reſulting, the various preparations are effected and produced, is very obvious; but of the manner, in which theſe are preciſely formed and conducted, we have at preſent but an imperfect idea, yet ſomething more ſatisfactory, it may be hoped, ſhall accrue from the indefatigable labour of chemiſts,

miſts, who have already demonſtrated, that the minute particles of two heterogeneous bodies, when intimately combined, poſſeſs a power to produce a mutual change upon one another; and have alſo found, that by the combination of different bodies, new bodies are produced, which are in all reſpects the ſame with thoſe produced by nature.

Whether the external form of plants likewiſe originates from their internal condition and compoſition, like what we obſerve in unorganized bodies, as ſalts, &c.; is a ſubject, in our preſent ſtate of knowledge, too early for diſcuſſion.

Organized bodies poſſeſs another power, already mentioned; which cauſes their determined figure; *Niſus Formativus* of Dr. Blumenbach.

Mr. Uſlar is of opinion, that the pollen of the flowers contains a very ſubtile, elaſtic, highly active matter, which gives the proper direction

tion to the Niſus Formativus, under altered circumſtances; this he concludes from the following obſervations.

1ſt, Becauſe hybrid plants deviate always in their form from that of the female, and aſſume more nearly that of the male;

2dly, As a proof of the elaſticity of this matter, it may be obſerved, that the pollen, which is depoſited, and which adheres to the viſcous humour of the ſtigma, cannot enter that organ, on account of the minuteneſs of the pores, or mouths of veſſels terminating on its ſurface. The impregnation muſt therefore proceed indirectly, or mediately, by means of an elaſtic fluid, which, being diſengaged from the pollen, is attracted by the liquid of the ſtigma; and, in combination with this liquid, penetrates the ſtigma, and paſſes to the germen; perhaps, there it acts as a ſtimulus, excites irritability, and thus produces alterations in the ſeed.

Irritability appears to be the principal effect; for, immediately after the depoſition of the pollen,

len, the embryo in the germen ſhows vitality or motion; the ſeed veſſels open themſelves, ſwell, and become filled with juices, which are gradually perfectionated in the germen.

There is ſcarcely any doubt, that the acceſs of air by this means, as well as in general by the combination of the food with the ſolid parts, has here a conſiderable effect. HALES ſuppoſes that it is probable, that the air contributes much to the concretion of the particles of bodies; and the ſuppoſition ſeems to be ſupported by the obſervations of Mr. Achard, that the formation, cryſtalliſation, or conſolidation of ſaline matters, is accelerated, and really occaſioned by the combination of gaſſes, ſuch as fixed air, &c.

The pollen diſcovers its elaſtic and inflammable nature, alſo when blown into the flame of a candle; in which caſe, not only the particles which come into immediate contact with the flame, but all the reſt are immediately kindled.

One of the moſt important ſubjects which can engage the attention of philoſophical botaniſts, is the irritability of organized bodies. This was demonſtrated with reſpect to animals, by the immortal Haller, and it is now more and more diſcovered to reſide in plants.

Haller diſtinguiſhes,

1ſt, Nervous power (*ſenſibilitas*), from

2dly, Muſcular power (*irritabilitas*).

Beſides theſe, we obſerve another in living bodies; that is,

3dly, Elaſticity (*elaſticitas*).

Very often are theſe three powers confounded, though they differ eſſentially from one another.

Elaſticity is common to all parts, but in different degrees. This power was well known to Bellini, De Gorter, Stahl, &c. The latter called it the *tone* of the fibre; and derived from it the irritability; which opinion is, however, now found to be erroneous; as elaſticity is a power different from all the reſt.

That it differs from irritability, is ſufficiently demonſtrated by Haller, Oeder, De Haen, Whytt, Zimmermann, Fontana, &c. vide Haller on Muſcular Fibre, &c.; of which Mr. Uſlar, the principal author of theſe fragments, has inſerted, in the German original, a ſhort extract.

The power of contraction of certain parts, exhibited after applied ſtimulus, is alſo evidently obſerved in plants, and is therefore not merely peculiar to animals.

Whatever deſtroys the irritability in animals, does the ſame in plants; as, for inſtance, violent electrical ſtrokes. Whatever excites irritability in animals, excites it alſo in plants. If the contraction obſerved in dionæa *muſcipula*, mimoſa *ſenſitiva*, averrhoa *carambola*, onoclea *ſenſibilis*, *&c.* be not conſidered as effects of irritability, what cauſe can be aſſigned for it?

Other inſtances have been given before, as, for inſtance, in the valliſneria; and there is another in nigella *ſativa;* at the time of impregnation of this plant, the antheræ and piſtillum incline towards each other, and remain in the ſame poſition until the impregnation be completed. Such motion cannot be called voluntary, as plants are conſidered to be deſtitute of volition; it muſt therefore be of another kind, excited by an internal ſtimulus. It cannot, as far as we know, ariſe from the influence of nerves, as theſe have never yet been diſcovered in plants. The principal modern authors who have written on this ſubject, are *Ellis*, *Medicus*, *Girtanner*, *Gmelin*, *Hope*, *Percival*, *Cavallo*, *Sömmering*, *Wriſberg*, *&c.*

All fibres do not poſſeſs an equal degree of irritability; and hence, all the parts of organized bodies are not equally irritable. The cauſe lies probably in the greater or leſſer acceſs of the principle of irritability, and in the various capacity of bodies for receiving it.

Thoſe parts appear to be moſt irritable which are moſt frequently moved.

Mr. Uſlar has alſo convinced himſelf that plants poſſeſs different degrees of irritability, without reference to their perceptible motion:

For inſtance, reſeda *odorata* is deſtroyed by an electrical ſtroke, which applied in the ſame degree to another plant, lepidium *ſativum*, does not hurt it in any degree.

The firſt is rendered ſickly or gangrenous by water mixed with ſuper-oxygenated muriatic acid, while the latter, when ſuch water is applied to its roots, becomes more vigorous.

In the ſpring, we often find that ſome plants, as phaſeolus *vulgaris*, &c. become gangrenous by the night's froſt; while others, as piſum *ſativum*, are never hurt by it; many other examples of this kind are obſerved in garden and foreſt trees, which prove the exiſtence of different degrees of irritability in plants.

We have farther to diſtinguiſh:

1*ſt*, Irritability, as the cauſe of many phenomena.

2dly, The principle of irritability.

The firſt is underſtood to be the capacity of the irritable fibre to receive the principle, and its power of contraction.

The other ſignifies the principle itſelf which animates the fibre, and without which this cannot exert its capacity or power by applied ſtimulus. From both theſe differs,

3dly, The ſtimulating irritating matter.

There is probably a very powerful penetrating principle difuſed throughout nature, and which affords the vital principle to all organized bodies.

Its exiſtence was acknowledged at all times, as far as we know; but as to its nature, very different opinions have prevailed. Plato and Hippocrates already ſuggeſted their opinion on that ſubject: The latter called the vital principle *το ἐνορμȣν*.

From the different degrees of irritability, which the ſame body poſſeſſes at different times, that is, in the two conditions or ſtates in which the irritable fibre may exiſt; namely, *1ſt*, When the principle of irritability is accumulated in it; and, *2dly*, When exhauſted of it; it follows, that irritability depends on ſome foreign matter or principle. Vide REHFELD, *an Vis Irritabilis Fibrarum Muſcul. inſita ipſis inhæreat, an aliunde ad eas accedat.*

This principle appears very probably to be an elaſtic fluid; and, according to Girtanner, it is the oxygen.

Oxygen is conveyed to all living bodies by the atmoſphere and by their food; and their parts variouſly poſſeſs more or leſs capacity for receiving it.

If oxygen is the principle of irritability; it will follow, that its different proportion in the irritable fibre, muſt occaſion different alterations.

If the irritable fibre contains the due proportion of it; then obtains,

1ſt, The healthy ſtate, which Girtanner calls the tone of the fibre.

2dly, If the fibre abound too much with this principle, then the firſt preternatural ſtate is cauſed, namely, that of ACCUMULATION.

3dly, If the muſcular fibre is deſtitute or deprived of it, then follows the ſtate of EXHAUSTION.

It has been before obſerved, that living bodies receive the principle of irritability by their food and from the atmoſphere. In order to prevent the accumulation of it, therefore, it is required, that ſome matter be applied to them, which ſhall deprive the irritable parts of the ſuperabundant portion; ſuch ſubſtances or matter, are called STIMULANTIA, or ſtimulating principles.

Now, if theſe are applied in a due proportion, correſponding to the increaſe of the principle, ſo that the fibres are deprived of the ſuperabundant portion, and retain only that portion which is neceſſary for their natural ſtate, then health is maintained.

If on the contrary, the ſtimulus applied, is diſproportionate, then two caſes are poſſible;

a. If the ſtimulus is too weak, then the fibres retain more than is neceſſary, and accumulation follows.—But,

b. If the ſtimulus is too great, then the fibres loſe the principle more rapidly than they receive it from without; and exhauſtion is the conſequence.

Exhauſtion may then be;

1ſt, Temporary, or

2dly, Irreparable.

The firſt continues until the fibre has recovered the principle of irritability; and till that period, the fibre is inſenſible to every ſtimulus, or no ſtimulus can produce contraction in it.

But on the contrary, the exhauſtion becomes irrecoverable, when the ſtimulus has been too great, *e.g.* in the caſe of a violent electric ſtroke, or application of ſtrong poiſons, ſo that the capacity of the fibre is deſtroyed, or the body is deprived of all its principle of irritability; then, gangrene or decay is the conſequence; the parts of the fibre become ſubject to the laws of chemical decompoſition, and putrefaction gradually follows.

Both, therefore, accumulation, and diminution or exhauſtion, of that principle are diſeaſes; the conſequence of the latter we have juſt obſerved; that of the firſt is the ſame.

By the accumulation, the fibres become too irritable; hence, the contractions they perform are more violent than they can ſuſtain. It is poſſible, that the conſequence ſhall be, either that the fibre, by too violent action, ſhall loſe its contractile power as far as this depends on the particular ſtructure; or, that the acceſs of the principle ſhall be cut off or interrupted by the loſt capacity of the fibre for receiving it. In either caſe, a relaxation follows which leaves no hopes for recovery, for the weaker ſtimulus has the ſame effect upon the fibre with accumulated irritability, as the ſtronger ſtimulus, *e. g.* electrical percuſſion or poiſon has upon that with the natural tone.

The effect of a froſt in the ſpring is thus explained; the greater the intenſity of cold, the more the principle of irritability is accumulated in the irritable fibre, becauſe the general ſtimulus heat is abſent, and becauſe, both for this and many other reaſons, more oxygen combines with bodies that are capable of receiving it, in a lower than in a higher temperature. In ſuch circumſtances, the principle accumulates ſo much in the fibres, that a ſmall portion of ſenſible heat is capable of inducing an irreparable exhauſtion.

Two examples which prove this theory, were experienced almoſt throughout Germany.

1ſt, In winter 1788-9, great deſtruction was occaſioned by the violent cold in foreſts and fruit gardens, though ſcarce any burſting of their veſſels, from expanſion of the water while freezing, was perceived in the trees, as there were no ſudden changes of temperature.

In the ſpring, the greateſt part of theſe trees produced flowers and leaves, which very ſoon thereafter, not only dried up, but the trees themſelves actually died. The ſame was obſerved in thoſe trees which were already in foliage, and had formed their fruits. This was the conſequence of too great irritability; from which the fibres, by the application of the uſual ſtimulus were greatly affected, and irreparably exhauſted.

2*d*, The month of April 1792 had already the appearance of June; in May, moſt plants were in bloom and in full foliage, and rich crops were expected: But by the froſt which happened on the 7th and 8th of May, all theſe flattering hopes were deſtroyed.

On the 11th, Mr. Uſlar collected the following obſervations:

a. The trees in the woods, on the eaſt and ſouth ſide, having been moſt acted upon by the ſun in the riſing of the day, had ſuffered more by the froſt, than thoſe ſituated towards the weſt and north. The leaves of moſt trees became gangrenous and decayed on the ſide expoſed to the ſun.

b. All kinds of trees had not ſuffered equally. The oak and beech had ſuffered moſt. Acer, fraxinus *excelſior*, betula *alnus*, had likewiſe ſuffered much; but carpinus *betulus*, betula *alba*, ſorbus *aucuparia*, had ſuffered much leſs, though they all ſtood mixed and interſperſed with the former. May not this be conſidered to ariſe from their different degrees of irritability?

It is well known to gardeners, that when night froſts prevail in the ſpring, it is neceſſary to protect the tender and moſt irritable plants with matts, and thus defend them, not only againſt the cold, but alſo againſt the ſudden effects of the ſun, and heat thereby induced.

The covering appears to prevent the accumulation of the principle of irritability in the fibre during the night; and alſo the too violent effects which would then be cauſed, by the ſtimulus of light and heat.

The increaſing temperature, as the day-light increaſes, affords already a ſufficient ſtimulus for them; plants are thus deprived of part of their irritability, which in due proportion, gives tone to the fibres, and by this they become gradually capable of ſuſtaining the ſtimulus induced upon them in the middle of the day without injury.

The change of the fibre from the accumulated ſtate to the moderate, and from this to the exhauſted ſtate, proceeds very quickly. Such changes, we obſerve in the phenomenon which is called the Sleep of plants. But the irritable fibre when exhauſted, recovers its irritability very ſlowly.

According to Mr. Uſlar's opinion, a plant, particularly an evergreen; as Ilex *aquifolium*, or quercus *ilex*, whoſe irritability has increaſed during the winter; if in the approaching ſpring, it were placed and well preſerved in an ice-houſe, would become ſo very irritable, that when afterwards taken out and ſuddenly expoſed to the warm atmoſphere of the ſummer, it would be ſo exhauſted in a ſhort time, that the capacity of its fibres would be entirely deſtroyed.

The irritable fibres of organized bodies have a connection or ſympathy with each other *(conſenſus)*, from which follows;

1ſt, That a ſtimulus applied to one is communicated to the reſt: But the effect of the ſtimulus thus applied to the fibres, is in general greater upon that which firſt receives it, and proportionally leſs upon the others as they are more remote.

If a branch of the mimoſa *pudica* be touched, it ſhrinks and collapſes; the ſtimulus which is produced by the touching, produces an effect upon the whole plant, but not equally upon all its parts.

2dly, If the ſtimulus applied to one fibre has an influence upon the reſt; it follows, that if the one is injured in any way, it muſt then likewiſe affect the other; that is, if one fibre be deprived of its principle of irritability, then the ſame change will take place in the other connected fibres, but in a leſs degree.

a. Becauſe the ſtimulus applied to one ſingle fibre, affects the whole ſyſtem of fibres, and every ſtimulus occaſions a loſs of a part of the principle of irritability.

b. Becauſe the reſt of the fibres afford ſupply to the exhauſted fibre, by parting with ſome of their own principle, provided this ſingle exhauſted fibre has not loſt its capacity for receiving it.

The more frequent the ſtimulus is applied, the more the fibre is deprived of its principle of irritability, the leſs irritable it becomes, the leſs is the effect of the ſtimulus, and the contraction is diminiſhed in proportion; if the fibre is quite exhauſted, then the effect of the ſtimulus ceaſes totally. This is one of the moſt intereſting facts which Girtanner has demonſtrated,

monſtrated, and which ſhall be more conſidered in treating of the ſleep of plants.

The degrees of contractibility is in proportion; to,

1*ſt*, The degree of irritability which the fibre poſſeſſes;

2*dly*, The intenſity of the ſtimulus.

As there exiſt different degrees of irritability and ſtimuli of different power.

Bodies when diſpoſed to come in contact with the irritable fibres, exert different effects upon them, according to the degree of attraction of the oxygen for them.

If the attraction of oxygen is greater for the foreign body than for the fibre; in this caſe the body takes the oxygen from the fibre, and the fibre loſes thereby its irritability; all bodies of this nature are called Stimulating Subſtances.

But, if on the contrary, the oxygen has a greater attraction for the fibre than for the body which is brought into contact with the fibre, then the body loſes its oxygen, which the irritable fibre takes up, and thence its irritability increaſes.

If the attraction for oxygen is equal in both, then no alteration takes place, and bodies of this kind do not increaſe nor diminiſh the irritability.

To the ſtimulating matters, belong: heat, light, electric matter, ſpirit of wine, carbonic acid gas, and all gaſſes which have a ſtrong attraction for oxygen, *viz.* hydrogen gas, &c.

Leaves immerſed in water impregnated with carbonic acid, ſoon loſe their irritability and fade. All bodies which contain oxygen, and which, when brought into contact with the irritable fibre, loſe their oxygen by a ſuperior attraction of the irritable fibre for this principle, increaſe the irritability of the fibre; *viz.* ſuperoxygenated muriatic acid, metallic oxyds, water, as this latter is decompoſed by plants; cold, in ſo far as by a diminution of ſenſible heat, one principal ſtimulus is leſſened, ſo that the fibre being leſs irritated, retains the oxygen from the decompoſed water, whence the irritability of the fibre is increaſed. A ſimilar effect of the accumulation of oxygen by cold, is obſerved in the manufacturing of paper; for paper made in the winter by a ſtrong cold, is much whiter than that which is made in the ſummer.

Heat as a ſtimulus excites the activity of the veſſels, and promotes vegetation in general; the living power is conſidered as an alternate contraction and extenſion of the fibres. Cicero already conſidered heat as the vital principle: "Omne vivum, ſive animal, ſive terræ "editum, vivit propter incluſum in eo calo-"rem."

As to the effect of the matter of heat, we know, that if it is applied as a ſtimulus to plants, proportionably to the irritability of the irritable fibre, it then promotes vegetation: But if the heat is proportionably greater than what the fibre can ſuſtain, in ſuch caſe, an irreparable exhauſtion and death will follow.

Heat always cauſes a diminution of the irritability of the irritable fibre, and this is neceſſary to prevent accumulation. Medicus has found, that the irritability of plants is greater in the morning, leſs in the middle of the day, and much leſs in the evening. Mr. Uſlar was well convinced of theſe facts by his obſervations reſpecting the ſleep of plants; he alſo found, that by long continued rainy weather and cool air, the irritability of thoſe plants, whoſe irritability is obſervable by contractions, was conſiderably increaſed. The proofs of the effects of a moderate heat promoting vegetation are numerous, and very obvious in hot-houſes, &c.

Many animals which hide themſelves during the winter, and remain apparently lifeleſs in their cells, diſappear, as Mr. Spallanzani has obſerved on the lacerta *ſalamandra*, at a ſeaſon when the temperature of the atmoſphere is much higher than in the ſpring when they again make their appearance. The cauſe of this phenomenon lies in the ſtate of irritability; in the autumn, the fibre is much exhauſted by the heat and light of the ſummer; but, in the approaching ſpring, the irritable fibre is in the accumulated ſtate, by the greater abſence of thoſe principles during the winter; in which caſe, a leſs degree of heat has a greater effect, than a higher temperature could produce in the autumn.

This explanation may with much propriety be applied to ſimilar phenomena obſervable in vegetables, and many other phenomena may be explained upon the ſame principles.

Vigorous is the growth of plants in the ſpring, quick the motion of their juices, and from month to month both decreaſe: By the approach of the autumn, vegetation is ſtopt, and in the fineſt days of the autumn, at which time it is even warmer than in the ſpring when plants grow ſo vigorouſly, the vegetable tribe is ſo abſorpt in ſleep, that the light of the ſun is then not capable to awaken them. The warmer the ſummer had been, and the more the ſun had ſhone, the ſooner the leaves of trees and plants change their colour; and the longer they retain their green colour, if the ſummer has been cool and the ſky much covered with clouds.

Plants which have ſtood all the winter through in warm rooms, grow but ſlowly in the ſpring when other plants grow very vigorouſly. In order to preſerve the plants growing in rooms, it is very proper to expoſe them occaſionally to a colder atmoſphere. Mr. Uſlar recommended this, and the reſults of experiments were always agreeable to his theory of irritability; it however muſt be done with caution, and the plants muſt not be too long expoſed to a cold air, nor in a very cold atmoſphere, elſe the principle of irritability accumulates too much, and the warmth of the room becomes then too great a ſtimulus, and injures the plants. This is not the only remedy for procuring new ſtrength to plants that grow in rooms, but any ſubſtance which ſupplies them with oxygen anſwers the purpoſe; as, for inſtance, moiſtening the earth in which they grow, with water containing a little ſuper-oxygenated muriatic acid; of which more will be mentioned in the following part.

Reſpecting the different degrees of irritability in different plants, Mr. Uſlar had made many obſervations.

Plants from warm climates, he found generally more active than thoſe from more northern. Jaſminum *azoricum* ſtill produced branches and leaves, when plants of a colder climate had long ceaſed to grow.

It appears to M. Uſlar, that the plants of northern climates, are more irritable than thoſe of the warmer climates; and although organized bodies, by change of climate, change in ſome reſpect their conſtitution in the following generation, yet we find that they retain always ſome difference reſpecting their irritability.

Moſt of the plants which have been tranſplanted from their warmer climates into our northern, part, for inſtance, later with their leaves, and likewiſe change their colour later, and not unfrequently we find the wood of a paler colour.

So, for inſtance, the wood of trees which grow nearly under the equator, is of a deeper colour, *viz.* ſwietenia *mahagoni*, cæſalpinia *braſilienſis*, hæmatoxylum *campechianum*, aſphalathus *ebenus*, *&c.* This is not merely limited to the wood, it is alſo obſervable in the green colour of the leaves. The leaves of trees of hot climates are generally of a deep green colour, *viz.* caſuarina *equiſetifolia*, or at leaſt they are of a deeper green than thoſe of the plants of northern climates.

Moreover, it is known, that the colour of animals living within the tropics, is not only deeper and more ſhining than of thoſe which live nearer to the poles, but that they alſo change their colour into a paler one when they are tranſported from thence into our northern countries.

The cauſe of the paler colour appears to be the preſence of oxygen, a ſuppoſition which is verified by the obſervation, that all vegetable ſubſtances which cannot part with oxygen are colourleſs.

This is ſhown by nature, and proved by experiments. If plants are placed in the dark, where they muſt retain the oxygen which they receive, they become paler and more irritable. Branches, or wood, which cannot abſorb it are white; plants which do not emit pure air, or only a very ſmall portion of it, *viz.* Fungi; lichen *parientinus*, L. *palleſcens*, L. *lacteus*, L. *ericetorum*, L. *miniatus*; melampyrum *nemoroſum*, *&c.* are almoſt colourleſs: but all the parts of plants, as leaves and calyx, and all plants which yield pure air, are coloured.

That oxygen is the principle of irritability, will be more fully proved by experiments. Plants acquire oxygen from their aliments, and from the air: they receive it by decompoſing the water. Plants take a certain portion of it combined with hydrogen and carbonaceous matter into their conſtitution: they part with ſome of the received oxygen again by the applied ſtimulus; and it appears that the deeper the colour is of plants or their parts, the leſs oxygen do they take up, and the more carbonaceous matter do they contain.

If oxygen be the principle of irritability, it will follow:

1ſt, That plants of a deep colour are more irritable than thoſe of a lighter colour: and from the deeper colour of plants of hot climates, we may conclude:

2dly, That theſe are leſs irritable than plants of northern climates.

That ſuch difference of irritability in plants exiſts, appears very evidently; for, if the plants of hot climates were not leſs irritable, the continual uninterrupted growth of plants within the tropics would be impoſſible: they would be exhauſted like thoſe of our countries, and they could not ſuſtain the ſtronger ſtimulus of light and heat: we may hence perceive, why barley ripens in Lapland in 60 days, and why it requires twice that time in France. The explanations now offered of the different abovementioned phenomena, are derived from the principles of the new theory; and deſerve highly the attention of philoſophers.

MR. GIRTANNER draws ſome general concluſions from the doctrine of irritability, ſuch are the following:

The irritability of living bodies always bears proportion to the quantity of oxygen which they contain; hence it may be deduced,

1ſt, That whatever increaſes the quantity of oxygen in organized bodies, increaſes alſo their irritability.

2dly, Whatever diminiſhes the quantity of oxygen in living bodies, diminiſhes at the ſame time their irritability.

The following experiments which corroborate what has been juſt mentioned, were made in ſupport of Mr. Girtanner's principles by Mr.

Uſlar, and they are confirmed by the obſervations of Mr. Von Humbold in his Flora Friburgenſis Subterranea; Mr. Uſlar took different ſeeds and plants, and cauſed an accumulation of oxygen in ſome, while no ſuch accumulation took place in the reſt: he found, that under certain circumſtances, the firſt germinated ſooner and grew quicker than the latter. In order to diſpoſe plants for imbibing more oxygen, it is neceſſary to apply to them bodies, which contain the oxygen but weakly combined, or from which it is eaſily ſeparable, and whoſe baſis has leſs attraction to oxygen than the vegetable matter has; ſuch a body is the ſuper-oxygenated muriatic acid.

Mr. Uſlar ſowed lepidium *ſativum* in two different pots, the earth of the one he moiſtened with pure river water, and that of the other with the ſame kind of water mixed with ſuper-oxygenated muriatic acid. The ſeeds in the latter germinated much ſooner than in the former, which was only moiſtened with pure water, and which conſequently could not communicate to the plants ſo much oxygen as the other, and thence too, the plants in it were much retarded in their growth. In theſe experiments it is to be obſerved,

1ſt, That the quantity of ſuper-oxygenated muriatic acid which is added to the water muſt not be too great; otherwiſe, it proves rather noxious than beneficial, as the oxygen accumulates, the plant becomes too irritable, and bad conſequences ſoon follow.

2dly, That the germinating plants, eſpecially thoſe which are impregnated with oxygen, are not to be immediately expoſed to the ſun rays; for light proves generally hurtful to the embryos and germinating plants, or while in their earlieſt ſtage; the cauſe of it is the too great irritability at this period, which however diminiſhes with the increaſing age of the plant.

Thoſe ſeeds which were moiſtened with an equal quantity of ſuper-oxygenated muriatic acid and water; and of which ſome were expoſed to the ſun, others kept in the dark exhibited very different phenomena; the firſt did germinate, but their colour ſoon changed; they became gangrenous and faded.

The latter germinated likewiſe, but they were left covered until the firſt leaf was evolved, and were not till then placed in the light: theſe made a rapid growth, and ſoon reached their ſtate of perfection.

Beſides what is above-mentioned, there is another chemical cauſe, whence the bad effect from expoſing plants ſuddenly to the light, may be derived; namely, it has been obſerved, that light has a ſtrong attraction for oxygen. It is this which renders the formation of ſuper-oxygenated muriatic acid ſo difficult, and which cauſes the ſeparation of oxygen from this acid when expoſed to the light of the ſun, ſo that the muriatic acid is then left behind in its common ſtate. Mr Uſlar convinced himſelf by experiments, that the common muriatic acid has a very different effect from the ſuper-oxygenated muriatic acid, very probably by reaſon of the weaker attraction of the oxygen in the latter acid.

The reſults from the experiments made with other ſeeds; as, for inſtance, with braſſica *campeſtris*, braſſica *napus*, lactuca *ſativa*, piſum *ſativum*, reſeda *odorata*, coincided with the reſults of the experiments before mentioned.

In order to aſcertain in a more ſatisfactory manner, that the greater proportion of oxygen cauſed the vigorous and quick growth of plants, Mr. Uſlar varied his experiments.

1ſt, He took pounded quartz inſtead of earth, and moiſtened one portion of it with the ſuper-oxygenated acid, another portion with pure water; the reſult was the ſame as in the former trials.

2d, He took a metallic oxyd, namely, oxyd of lead or litharge, and he found that the plants grew very well in it, and better indeed than in pure earth. This proves beſides, that all metallic oxyds do not deſtroy plants.

Mr. Uſlar alſo made the following experiments, in confirmation of the hypotheſis, that oxygen is the principle of irritability.

He moiſtened, with ſuper-oxygenated muriatic acid, earth in which he had planted mimoſa *pudica*, and droſera *rotundifolia*, and he thereby brought them, not only to the higheſt degree of irritability, but he found that if he continued the accumulation, the light had ſo great an effect upon them, that they were deſtroyed by that ſtimulus. Other plants which ſhowed ſcarce any marks of irritability, ſoon became irritable; all loſt their irritability, often to irreparable exhauſtion, when too often and too long ſtimulated, and when the ſupply of irritability was cut off.

The different degrees of capacity of different plants were alſo obſervable, as ſome took up ſo much oxygen from the ſame impregnated water, that they loſt their proper colour and died; while others of different ſpecies, continued to grow vigorouſly.

It appears that the durability of organized bodies, particularly of plants, bears a certain proportion to the time in which they come to their perfection.

Forreſters have frequent occaſion to obſerve, that not only trees which grow very faſt are of ſhorter duration, than thoſe which require a longer time to come to their perfection; *e. g.* ſalix, betula, populus; compared with quercus, fagus, acer; but alſo, that thoſe whoſe growth has been accidentally accelerated, ſeldom arrive at the uſual age which nature had determined for the ſpecies to which they belong. Not unfrequently we find, that trees ſicken when growing in too rich ſoil. Of this Mr. Uſlar was ſatisfied by experiment: by the increaſed ſupply of oxygen, and by plenty of food, the irritability is increaſed, and conſequently the growth haſtened: but he alſo found, that plants thus hurried on to bloſſoming and perfection, were not of ſuch durability as thoſe which arrive at thoſe ſtates in the natural courſe of time.

Pure air (oxygen gas) is in general favourable to vegetation, and even neceſſary to it; but azotic gas, and hydrogen gas, when plants are included in them, prove fatal to them. Yet there are exceptions as to both, not only in certain circumſtances which ſhall be mentioned on another occaſion; but alſo according to the various conſtitution of different plants.

Some plants grow better in bad air than in an air which contains much oxygen: Plants growing in deep mines are examples of this; for if ſome of them are removed and expoſed to atmoſpheric air, they ſoon die; many of the byſſi, lichenes, agarici, &c. grow not only in azotic or hydrogen gas, but even better than they do in the common atmoſpheric air, and they will not grow at all in pure air. The cauſe of this appears to be the want of a ſufficient portion of hydrogen for their proper compoſition, and alſo the great irritability of their fibres, while the principle of irritability is not proportionably accumulated to ſuſtain the ſtimulus.

The vital power of plants was formerly ſuppoſed to be derived from the aſcent and deſcent of the juices, and this motion again, from the attractive power of the veſſels for the nutritious juice; juſt as fluids riſe in capillary tubes, from the attraction of the glaſs for the fluid: in like manner, a number of capillary tubes were imagined to exiſt in plants, extending from the roots to the extremities of the branches, and in which the juice roſe upon the ſame principle as in capillary glaſs tubes.

This explanation Mr. Uſlar contends to be repugnant to ſound phyſiology, and he thinks that it is impoſſible that by this power alone, the juice can be conveyed to the extreme points of high trees.

Hales conſidered the aſcent of the ſap as the effect of heat and air, by which the juices were attenuated and more diſpoſed for aſcending, but this hypotheſis appears very unſatisfactory. The doctrine of irritability leads to another theory, which is ſupported by many facts.

Without internal activity and contractility of the fibres, the quick circulation of the juice in many plants could not take place: were this effected by heat, it muſt be expected that the circulation ſhould be quicker in the ſummer than in the ſpring; but we find, that the circulation of the ſap in plants is quickeſt and moſt copious in the ſpring, when the plants are moſt irritable.

Mr. Von Marum has now decided this point in a diſſertation, *De Motu Fluidorum in Plantis*. Groningen, 1773; towards the end of it he ſays:

" Videtur veriſimillimum, ipſis plantarum vaſis actionem quandam eſſe attribuendam, quæ abſorptos humores profundat verſus illam partem, quæ minorem offert reſiſtentiam; quænam autem ſit illa actio, inquirendum reſtat.

" Diametro alternatim diminui aut augeri plantarum vaſa, et hac ratione contentos humores

" mores urgeri, ex una vaſorum parte verſus al-
" teram, requiri videtur.

" Utrum vero hæc vaſorum conſtrictio oria-
" tur a vi quâdam contractili ipſis inſitâ, quæ
" a contractilitate vaſorum animalium non di-
" verſa eſt, an vero ab aliâ quâdam vaſorum fa-
" cultate derivanda, haud facile determinare li-
" cebit."

It appears probable, that the veſſels of plants poſſeſs a contractile power, ſuch as Haller called irritability in animals. And it has been demonſtrated by many experiments, that the diminution and extenſion of the diameter of the veſſels, is produced by means of the ſpiral and circular fibres.

When Mr. Marum obſerved that milky juice flowed from the end of a branch of euphorbia when freſh cut, he immediately endeavoured to enquire into the cauſe of this phenomenon; and he compared it to that cauſe, to which the bleeding muſt be aſcribed, when ſmall veins of animals are cut aſunder, *viz.* the alternate contraction and dilatation of the veſſels, during the circulation of the blood in animals.

Irritability is the cauſe of contraction; if the contraction in the veſſels of plants ariſes from it, it will follow that their action will ceaſe as ſoon as the irritability of the fibres is deſtroyed: and if ſuch ſhall be found to be the caſe, it may be deduced;

1ſt, That contraction cauſes the flowing of the juice from the veſſels.

2dly, That the cauſe of the contraction muſt be derived from the irritability.

3dly, That this, and its effect contractility, muſt cauſe the circulation of the juices.

In order to be convinced of the aſſertion, that ſtrong electric ſhocks kill animals, by depriving them of, or deſtroying the irritability of their irritable fibres, Mr. Marum for want of amphibious animals, which retain ſome of their irritability for a conſiderable time after they are killed, took eels *(muræna anguilla)*, which, as is known, poſſeſs the ſame power. By means of the Teylerian electric machine, he paſſed ſhocks through ſeveral of theſe animals, and the reſults of his experiments were;

1*ſt*, When the ſtream of electric matter pervaded the whole animal from head to tail, it died immediately, and no mark of irritability could be diſcovered, even in its ſmalleſt parts, by any ſtimulus whatever.

2*dly*, But if the ſtream was directed through certain parts of the animal only, then he found that thoſe parts only had loſt their irritability, and conſequently their contractile power.

Theſe experiments, tried upon animals with warm blood, ſucceeded of courſe equally, as the irritability of their muſcular fibre does not remain ſo long after death.

Theſe experiments ſufficiently proved, that the irritability of animals was ſuſpended by the electric ſhocks; in order to aſcertain the ſame with reſpect to plants, he took various ſpecies of euphorbia, *viz.* euphorbia *campeſtris*, (perhaps *eſula*) euphorbia *lathyris*, euphorbia *cypariſſias*, and ſent a ſtream of electric matter through them; he then cut off the ſtem, but no mark of effuſion of the juice was now obſerved; the ſame was remarked in ficus *carica.*

If the ſtems of theſe were afterwards ſqueezed with the fingers, then ſome juice was forced out as long as the preſſure was continued, which afforded a proof, that a certain power which had cauſed the effuſion in former trials was now deſtroyed (namely irritability.)

By ſending a ſtream of electricity through ſingle ſtalks of theſe plants, the reſult correſponded with the experiments upon certain portions of animals, as in this caſe, only the particular part which had ſuſtained the ſhock had loſt its irritability.

It is not electricity alone which produces this effect in plants; there are other ſtimuli which may effectuate the total exhauſtion of irritability, on which the contraction of the ſpiral and circular fibre depends. Mr. Uſlar ſucceeded at different times in experiments with euphorbia *peplus*, and *eſula*, whoſe irritability he had highly accumulated, by increaſing the ſupply of oxygen, and by removing the habitual ſtimuli of heat and light, ſo that when he expoſed them afterwards ſuddenly to the light of the ſun when in the zenith, they became gangrenous and dry in a ſhort time. Mr. Uſlar cut off from time to time, the ſtalks as they approached to this ſtate; and he found, that although the efflux of the juice did not totally ceaſe before they died, yet it was conſiderably diminiſhed, in compariſon with what was obſerved in other plants of the ſame kind which had their proper tone.

From what has been obſerved on this ſubject, it follows:

1ſt, That the contraction of the vegetable fibre is owing to irritability, as well as that of the animal fibre, and that both are ſubject to the ſame laws.

2dly, As the cauſe of the circulation of blood in the animal body, is derived from the irritability and contraction of the fibres and veſſels, we may ſuppoſe with ſome propriety, that the circulation of the juices in vegetables, may be effected by ſimilar means.

ANOTHER remarkable phenomenon which is probably connected with irritability, is the ſleep of plants.

The animal body requires reſt, *i. e.* ſleep; this is the ſtate, during which the fibres and organs recover new powers for future activity, which they had loſt by their frequent exertions.

The ſtate of plants which is called the ſleep of leaves, or more generally, of plants, appears to Mr. Uſlar to be ſimilar to the ſleep of animals; and though we do not perceive it by external marks in all plants, it does not thence follow, that ſuch do not enjoy it, or that their fibres do not become exhauſted, nor require any time for reſt.

There are but few plants, in compariſon to the great number of plants produced, that ſhow irritability by viſible contractions, and yet all plants are more or leſs irritable. If we conſider the cauſe of the ſleep of plants, it will appear the more probable, that this phenomenon does exiſt in all plants.

Long before Linné, it was obſerved that plants enjoyed reſt at certain times. Garzias obſerved this firſt in tamarindus *indica;* afterwards Dr. R. Camerarius wrote a diſſertation, De Herba Mimoſa l. ſentiente, in which the ſubject was more fully treated; at laſt appeared the great Linné; his attention to that ſubject, was particularly engaged by the lotus *ornithopodioides;* he then demonſtrated the ſleep of plants, directly by obſervations and experiments, and ſhewed that it naturally took place in plants, ſucceeded regularly, and was independant of any extraordinary accidents.

With reſpect to the ſleep of plants, he alſo obſerved many circumſtances analogous to that

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of animals, *e. g.* that young plants like young animals, ſleep longer than thoſe fully grown up. The cauſe ſeems to lie in the different degrees of irritability in different ages.

Sleep is reſt, the time when fibres and organs recover from their relaxed or exhauſted ſtate, which has been induced by the living activity or irritability.

The whole organization is not deprived of activity by ſleep, for the uninterrupted motion does not ſtop; this only takes place after death.

Animals and plants generally chooſe the night for their reſt, becauſe two habitual ſtimuli, light and heat, are then either altogether or moſtly abſent.

Plants which are only active in the night, are perhaps too irritable, and animals which are awake in the night, are not unfrequently forced to it by fear, and the particular economy of their life.

The ſleep of man, conſiſts principally in reſt of the nerves of the brain; the more perfect this is, the more completely are ſuſpended ſenſation and concioufneſs, and with the geater power do men awake again for new activity. If the fibres of their body be too irritable, if the ſtimulus, for inſtance, of heat, aliment, ſpirituous ſubſtances, are not ſufficiently withdrawn, then the muſcular fibre thereby ſtimulated, acts upon the ambient nervous fibre, the impreſſion is communicated to the brain, and the ſleep is leſs quiet, and leſs ſound.

The greater the previous exertions of the animal body have been, and the more irritable it was, the greater is the relaxation.

Motion is a mechanical ſtimulus upon the irritable fibre: Mr. Sauſſure obſerved, that a moderate motion which he made on the ſummit of Mount Blanc, fatigued him more than a conſiderable one on flat land; cold, or perhaps pure air on the mountain made the fibre too irritable, and the motion as a ſtimulus, was out of proportion to the irritability.

The ſame laws are obſerved in plants. The more they are excluded from heat and light during the night, the more perfect is their ſleep; the more irritable they are, the ſooner they are exhauſtable, and the greater the ſtimulus is, and the longer it is continued, the more they are exhauſted.

By means of a continual ſtimulus, the perceptible irritability of a mimoſa may be aboliſhed or ſuſpended. All this leads to the analogical concluſion, that plants may be relaxed like animals, and that both require a time in which they may collect new powers, (*i. e.* accumulated principle of irritability), in order to become fit again for further exertion.

The congregation of nerves in animals exiſts particularly in the brain, every ſtimulus induced upon the irritable fibre, is communicated through this to the others, by acting upon the annexed nervous fibre, whereby animals perceive impreſſions upon the ſenſes; by removing the ſtimulus, and by the exhauſtion of the irritable fibre, concioufneſs and a certain degree of ſenſation are ſuſpended, the nerves receive no impreſſions; and if their fibres, like the reſt of the animal body, are capable of relaxation, they then have time to recover their powers.

Abſence of ſtimulus, and diminution of irritability, are therefore the cauſe of ſleep; and aboliſhed ſenſation, or a diminution of ſenſation, are merely the conſequence of thoſe cauſes.

We cannot therefore ſay, that all organized bodies, in which we do not perceive evident marks of ſenſation or concioufneſs, muſt be alſo incapable of ſleep, the concluſion would be as inconſequential, as if we were to aſſert, that all animals which are deſtitute of brains, are alſo incapable of ſleep; or that thoſe beings were deſtitute of ſenſation, becauſe in animals which have a brain, ſenſation depends particularly upon that organ. Have not inſects ſenſation, though they have only nodes of nerves inſtead of a brain? Do we not perceive ſenſation in worms, in which no nerves have yet been diſcovered?

vered? And do not all theſe beings ſleep? Many obſervations might be produced in confirmation of this ſuggeſtion.

Mr. Uſlar after having made many obſervations reſpecting the marks of ſleep in inſects; draws the following concluſions, that all bodies which poſſeſs irritability require ſleep, *i. e.* that periodical reſt is neceſſary for them, during which they recover from their exhauſted ſtate, and collect new irritability.

Many experiments which ſhew that plants by too frequent, long continued, and violent ſtimulus, become exhauſted and relaxed, led him to this concluſion, that the uncommon poſition which we perceive at certain times of one or other parts of plants, is really a ſtate of reſt, and ſimilar to the ſleep of animals.

That during this time the growth is not ſtopped, cannot be propoſed as an objection, becauſe animals grow likewiſe during ſleep; their power of reproduction proceeds, ſo does their reſpiration and digeſtion.

We find that different animals fall into particular poſtures when aſleep, and that ſome do not ſhow any external marks of ſleep; and that there is great diverſity as to the time and the duration of ſleep in different animals: we find ſimilar varieties in plants.

Some plants ſleep in the night time only, others ſleep alſo during certain hours in the day, ſome diſcover the ſtate of reſt clearly by their external appearance, and others again, manifeſt very ſlight or ſcarcely any marks of ſleep; ſolanum *nigrum*, ranunculus *repens*, *&c.* ſhut their flowers ſome hours in the day, ſpiræa *filipendula*, *&c.* is ſhut in the middle of the day, cactus *grandiflorus*, opens the flower only at the ſun-ſet, and ſhuts it in the morning, meſembryanthemum *noctiflorum*, awakes likewiſe only in the night.

Some plants when at reſt, join the upper ſides of their leaves, *viz.* alſine *media*, others fix them on the ſtalks, like œnothera *mollis*, *&c.* In ſome, the leaves become erect, in others they droop or fall down.

Linné has mentioned all theſe various diſpoſitions of the leaves, in his Philoſophia Botanica, and in the Amœn. Acad. IV. §. 340. *et ſeq.*

It was obſerved, that the cloſing and opening of the leaves and flowers of certain plants, varies according to the weather and condition of the air; ſuch were called Flores Meteorici: others which varied according to the length and ſhortneſs of the day, and which ſhut at ſun-ſet, were called Æquinoctiales; and thoſe which did ſo at certain hours in the day, were denominated Tropici. From obſervations of the laſt kinds, Linné formed the horologium *floræ.*

Several authors who have written on this ſubject, attribute the general cauſe of it to light and humidity. Mr Uſlar agrees with them, and allows both; but he takes the whole in rather a different ſenſe, and adds, that whatever acts as a ſtimulus to the irritable fibre, may contribute to the effect; therefore, not only light and humidity, but alſo heat and alteration in the ſtate of the atmoſphere; as, for inſtance, the degree of electricity, the admixture of carbonic acid gas, have influence upon the ſleep or reſt of plants.

We know the effect of electricity upon the irritable fibre of the organized body, and the influence of it upon vegetation in general will be afterwards demonſtrated; we ſhall here only obſerve, that moſt plants which diſcover ſtrong marks of ſleep by their external form, have pinnated leaves (folia pinnata.)

Light, heat, hydrogen gas, are matters which act as ſtimuli upon the irritable fibre; if the fibre is too irritable, then exhauſtion and the ſtate of reſt follows.

Without light, or in abſence of it, without hydrogen gas, plants cannot continue nor perfect their growth; proofs of this we obſerve in plants placed in atmoſpheric air excluded from light, and in thoſe which are alſo excluded from light, but ſurrounded by hydrogen gas;

for inſtance, plants which grow in deep mines, filled with bad air.

Both theſe act as ſtimuli, and deprive the plants of the ſurplus of oxygen, that is, of the accumulated irritability.

If the ſtimulus is too great, too frequently applied, or too long continued, then exhauſtion follows, the fibre is of courſe relaxed; this is obſervable in many, partly by the interrupted external motion, partly by the marks of ſleep.

Heated air, and the heat of the ſun relax animals and plants; hediſarum *gyrans*, we find, ceaſes to move in the middle of the warmeſt days, particularly if by previous circumſtances, *e. g.* low temperature, or moiſture, the irritability of the fibre had become accumulated.

Mr. Uſlar found the ſame reſults in experiments with the mimoſa, if the irritability had been increaſed; he obſerved that the leaves and ſtalks collapſed ſooner than uſual, according as the ſun had ſhone ſhorter or longer upon them, and by no other means was he able to awaken them from their ſleep, than by applying ſuch a body as could afford a freſh ſupply of oxygen.

If we only look into gardens, foreſts, meadows, we perceive that plants which have been relaxed and deprived of moſt of their irritability by heat, are quickly recovered by rain; for in this caſe the water affords the oxygen, and agreeably to our new theory, replaces the loſt irritability.

Plants in their natural ſtate all follow thoſe laws, which have been already noticed. Moſt awake at the riſing of the ſun, and return again to a ſtate of reſt at ſun-ſet.

In ſhort, plants are found to be more irritable and more active in the morning; exhauſted, leſs irritable, leſs active in the evening; and it appears that diminiſhed irritability is the cauſe of the phenomenon called the ſleep of plants; be it in the middle of the day, or in the evening, early r late in the day, the cauſe lies always in the ſtate of the irritable fibre; all are ſubject to exhauſtion and relaxation, and all require a time wherein they may recover new ſtrength. Thus Linné De Somno Plantarum: "ut quiete "tranquillâ fruentes novas quaſi vires recupe- "rent."

Suppoſe the ſtimulus which cauſes the relaxation is not removed; is it notwithſtanding poſſible that plants can fall into a ſtate of reſt? Why not? the ſtimulating matter is only active as the fibre poſſeſſes irritability. It is therefore, not againſt the principles of our theory that the portulaca *oleracea*, ſpirea *filipendula*, *&c.* ſhould ſhut in the middle of the day; and although the latter awakes only in the morning towards nine, yet the cauſe why its fibres ſuffer a temporary exhauſtion in the day, lies in their greater irritability: this may be ſaid of all thoſe plants which ceaſe to be active in the afternoon about four or five; and the reaſon why theſe require a longer time for recovery, depends on the peculiar capacities of the fibres to regain the oxygen of which they had been deprived.

The more irritable animals and plants are, the more readily and the ſooner they become relaxed, and the more frequently they require reparation: If, therefore, portulaca *oleracea*, folds up ſo early as 11, the cauſe is to be ſought for;

1ſt, In the ſpecifically greater degree of irritability of the fibres:

2dly, In the greater irritability which it poſſeſſes in the morning.

Its irritability is at this time too great, and therefore not in proportion to the ſtimulus; the fibre is exhauſted: and the ſtimulus becomes only active again, when the principle of irritability has been again accumulated, and this takes place only as far as theſe ſtand in a more equal proportion with each other.

Many other phenomena may be explained upon the ſame principles. But it may be aſked, if exhauſtion of the irritable fibre is the cauſe of the ſleep of plants; how does it happen that the fibre is not irreparably exhauſted when the ſtimulus is not removed? To this Mr. Uſlar replies, that when an irreparable exhauſtion does take place, an uncommonly great accumulation, cauſed *e. g.* by a great or intenſe cold, muſt have previouſly exiſted; and in this caſe, the ſtimulus acts not as being too long continued, but as being unproportionable and too violent, hence it deſtroys the capacity of the fibre. As long as the fibre retains the capacity to receive irritability anew, the exhauſtion is only temporary; but if plants are deprived of that diſpoſition by which they receive the principle of irritability, then the temporary exhauſtion is changed into an irreparable one; this we obſerve to happen by a too long continued heat and drouth, and by a dry electric atmoſphere: if the plants are only relaxed, and not totally exhauſted by the greateſt degree of ſtimulus, and if they ſtand in connexion with bodies from which they can receive a freſh ſupply of the principle of irritability, then the effect of the ſtimulus is only ſuſpended, and only until the fibre is become irritable again.

HILL ſays in his diſſertation on the Sleep of Plants:

" When he made the light fall upon plants " in different degrees, he found that their ſleep " was accordingly more or leſs perfect. Or that " the more intenſe the light is which falls upon " on plants, the more is their irritability, their " principle of life ſet in activity; and the leſs " the ſtimulus is in proportion to their irritabili- " ty, the greater degree of irritability remains " in the fibres, and the more ſenſible they re- " main.

He ſays farther:

" According to the degree of light he had " applied, was likewiſe the degree of ſleep." *i. e.* the greater or leſs the degree of ſtimulus to a certain point has been communicated, the more or leſs the fibre is exhauſted and relaxed, as on this depends the degree of ſleep.

In animals we obſerve the ſame, their ſleep is more ſound when they have been more ſtimulated; but too violent ſtimulus occaſions a revolution in their body which approaches to diſeaſe, and from which they ſlowly recover, ſooner, however, or later according to circumſtances.

If we will not acknowledge the irritability of plants, if we do not admit, that the ſun's light acts as a ſtimulus, and that by it the irrritable fibre can be exhauſted; it then muſt appear a myſtery, why plants ſhould ſhow indication of taking reſt at the time when the ſun is in the zenith, while it is allowed by botaniſts, that the ſun's light animates vegetables. But ſhould not the following facts be deemed a proof of the irritability of plants, its exhauſtion and accumulation? *viz.* that all the phenomena already mentioned, can be produced by other ſtimuli beſides light, *e. g.* hydrogen gas, and carbonic acid gas; for the effects of theſe upon plants are ſimilar to thoſe of light; the plants undergoing ſimilar changes in perfect darkneſs, when expoſed to them, as by the application of light.

PLANTS, as we know, have different kinds of irritable fibres, ſtraight, circular, and ſpiral; a ſtimulus applied to them occaſions contractions, which appear according to the nature of the fibre by decurtation of the fibre, by diminution of diameter, or periſtaltic motion.

HEDWIG aſſerts, that the origin and formation of the leaves and flowers are effected by the ſpiral veſſels: when, therefore, a ſtimulus acts upon the fibre, a contraction enſues, and plants are forced mechanically to give the leaves and flowers a certain direction, and thus contract particular parts or extend them.

If the vegetable fibre is deprived of its irritability, it flags, the ſtraight fibre is then elongated, the others extend their diameter, and thus naturally follow different poſitions of the ſtalks and leaves.

In this manner, Mr. Uſlar imagines the opening of the flower is effected; if light, a moderate heat, or other ſtimulus acts upon the fibres and veſſels of the calyx and petals, they contract, and the flower opens, to which certainly the life of the whole plant aſſiſts. The periodical cloſing of many flowers may likewiſe be explained by the extenſion of the contractile fibres and veſſels.

Mr. Uſlar has convinced himſelf by many experiments, of the juſtneſs of Dr Ingenhouz's obſervations, that many plants would ſurely die in hot weather in a few days if they had not time during the night for reſt. He found cucurbita *pepo*, in the middle of a hot ſummer's day, lying on the ground exhauſted and flaccid, he thought to recover it by moiſtening it with water, but in vain; probably the capacity of the fibre was not then ſo great as to receive immediately, without removing the habitual ſtimuli, light and warmth, ſo much oxygen from the water as would have been neceſſary to its complete recovery, and to collect this, reſt during the night was requiſite, when the altered temperature and modification of the atmoſpheric air, and abſence of light, are favourable for the reſtoration of the tone.

Here Mr. Uſlar reminds us of the obſervation, that moſt of plants are hurt by moiſtening them with cold water in the middle of the day when the temperature is higheſt; for although they exhibit for a ſhort time a vigorous appearance, yet this is only tranſient, and not unfrequently they die preſently thereafter. The cold of the water, and the oxygen communicated by it, eaſily induce accumulation, which is ſucceeded by irreparable exhauſtion.

FINIS.